BEFORE THE
NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D.C.

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In the matter of the investigation :
of the accident involving :
Trans World Airlines, Inc. :
Flight 800, B-747-131, N93119, :
8 miles south East Moriches, :
New York on July 17, 1996 :
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Baltimore Convention Center
Halls A and B
One West Pratt Street
Baltimore, Maryland 21201-2499

Thursday, December 11, 1997

The above-entitled matter reconvened for hearing pursuant to notice, at 9:00 a.m.

APPEARANCES :

Board of Inquiry:

Honorable Jim Hall Chairman	Member NTSB
Dr. Bernard Loeb	Director, Office of Aviation Safety
Dr. Vernon Ellingstad	Director, Office of Research and Engineering
Mr. Barry Sweedler	Director, Office of Safety Recommendations and Accomplishments
Mr. Dan Campbell	General Counsel

Technical Panel:

Thomas Haueter	Chief, Major Investigations Division
Al Dickinson	Investigator-in-Charge, Operations

Also Present:

Debra Eckrote
Norman Wiemeyer
Malcolm Brenner
James Wildey
John Clark
Frank Hilldrup
David Mayer
But Simon
Henry Hughes
George Anderson
Doug Wiegman
Mitchell Garber
Merritt Birky
Dan Bower
Dennis Crider
Robert Swaim
Charles Pereira
Deepak Joshi
Larry Jackson

Parties:

Lyle K. Streeter	Air Safety Investigator, Department of Transportation, FAA
Captain Jerome Rekart	Chief Accident Investigator, Air Line Pilots Association
Captain Robert Young	Director of Flight Operations Safety, Trans World Airlines
J. Dennie Rodrigues	Senior Air Safety Investigator, Boeing Commercial Airplane Group
Fred Liddell	Chief Investigator, International Association of Machinists and Aerospace Workers
Hal Thomas	Technical Engineer, Honeywell
Raymond Boushie	President, Hydro-Aire

I N D E X

EXH I B I T S

PRO C E E D I N G S

(Time Noted: 8:55)

CHAIRMAN HALL: We will reconvene this public hearing of the National Transportation Safety Board that is being held in connection with the investigation of an aircraft accident involving Trans World Airlines Flight 800, a Boeing 747–131 that occurred eight miles south of East Moriches, New York July 17th, 1996.

I would like to ask those in the audience that would like to observe to please sit down and take their seats. For those who are observing these proceedings, I would remind you that you can follow them and obtain additional information on the NTSB web site, which is www.ntsb.gov.

We have this morning -- before we begin the Aging Aircraft Panel and the Flammability Reduction Panel which will follow, let me state that I have been -- there have been inquiries from the parties, from the media and from everybody “are we going to finish today?” -- and I don’t think there have been, you know --

Let me say that it is the intent of the Chairman that we have two very important agenda items. Both of these agenda items need -- both of these panels need –– need full time and discussion.

If we can have a full discussion and presentation and all the parties and everyone feels like they have had an opportunity to participate, we might finish today, but –– however, I don't think it is very likely.

But, if we –– well, we will just have to see how the program moves us rather than -- I don't want to set some artificial deadline that we all have to meet, because I think these next two subjects are important, important they be covered in the same type of detail that we have covered the rest of the hearing.

I really appreciate everyone's patience. I know we are into day four now, and -- but, I appreciate everybody –– I appreciate everyone's attention, and I just want to be sure that we continue to do as thorough a job on these next two panels as we have done on the previous panels that have preceded it.

SO, again, I thank the parties for their attendance this morning. I acknowledge the witnesses and ask Mr. Dickinson, please, to swear in and introduce the next panel which is on Aging Aircraft.

MR. DICKINSON: Good morning, Mr. Chairman. Would the panel members please rise and raise your right hand?

(Witnesses comply.)

Whereupon,

GREGORY DUNN, BILL CROW, GEORGE SLENSKI, KEN CRAYCRAFT, IVOR THOMAS, ALEX TAYLOR AND ROBERT VANNOY

were called as witnesses by and on behalf of the NTSB, and, after having been first duly sworn, were examined and testified on their oath as follows.

MR. DICKINSON: Thank you. Please be seated. This morning's panel consists of Mr. Robert Vannoy, Mr. Ivor Thomas, Mr. Alex Taylor, Mr. Ken Craycraft, Mr. George Slenski, Mr. Bill Crow and Dr. Gregory Dunn. They will be questioned by Debra Eckrote, Robert Swaim, Jim Wildey and Norm Wiemeyer.

Mr. Robert Vannoy is a Boeing Company employee. He has been with the company for thirty-two years. He is the current Chief of the 747 Fleet Support. For the last sixteen years he has supported the 747 fleet through the Customer Services Division, has been involved with developing programs to analyze and maintain the structural analysis on models 737, 747 and 767.

He is active in a variety of industry activities related to aging aircraft structure, including the Air Transport Association's Airworthiness concern process. He has a Bachelor's Degree in Engineering.

Mr. Vannoy, would you please identify yourself?

(Witness complies.)

Thank you. Mr. Ivor Thomas; this is his third panel this morning. He is still the Chief of fuel systems and auxiliary power units and he has been with the Boeing Company for thirty-one years. Just to reiterate, he has a B.S. degree in Mechanical Engineering from Bristol, England.

CHAIRMAN HALL: That's pretty good if he is still in that position.

(Laughter.)

MR. DICKINSON: The third is Mr. Alex Taylor. Please identify yourself.

(Witness complies.)

Thank you. He is a Mechanical Engineer from the Boeing Commercial Airplane Group, and he has been at Boeing for thirty-seven years. He is an Associate Technical Fellow of the company and since 1974 has worked in the Electrical System Standards organization creating and maintaining Boeing standards for electrical parts, materials and processes.

He is responsible for a variety of airplane electrical wire and cable activities, including research and development of new materials and test methods, creating and maintaining the Boeing process specifications that define the engineering requirements for the assembly and installation of airplane wire bundles, creating and maintaining the technical content of the standard wiring practices which each airline operator uses to maintain the airplane's electrical wiring. He has a Bachelor's Degree in Applied Physics from Royal Technical College in Glasgow, Scotland.

Next we have Mr. George Slenski. Please identify yourself.

(Witness complies.)

Thank you. Oh, excuse me, I will go in order here. Let's back up to Mr. Ken Craycraft. Thank you. He is a Maintenance Engineer for TWA, provides technical support to the Maintenance Department for correcting difficult and/or repetitive malfunction in the electrical systems on TWA aircraft. He provides analysis of causes for mechanical delays and recommends methods for improving the reliability of the company aircraft.

He is a TWA designated representative at government and industry meetings, and he is trained in Boeing 727, 747, 767 models, and DC-9 and 10's and MD-80's, and also Lockheed L-10-11's. He has a degree in -- from the Central Technical Institute.

Now we will get to Mr. Slenski. This has, again, been his second panel, I think. He is the Lead Engineer for the Electrical Material Evaluation Group at Wright Laboratory and has been there for seventeen years.

Next we have Mr. William Crow. Please identify yourself.

(Witness complies.)

He is with the Federal Aviation Administration and has been in Aviation Maintenance for forty years. He is currently the FAA’s Supervisor, Principal Maintenance Inspector for American Airlines in Dallas/Fort Worth Airport in Texas.

Previous to his current position, some of his experience includes he is a Certificate Manager and he is an NASIP and RASIP Team Manager and a Regional FAA Flight Standards Service Specialist.

In addition, he has served in various maintenance positions in the Air Force National Guard. He has a pilot’s certificate with an instrument rating, and he is a certificated air frame and power plant mechanic.

Last, but not least we have Dr. Gregory Dunn.

(Witness raises his hand.)

Thank you. He has been in the Aerospace

industry for twenty-five years. He is currently a member of the FAA Transport Standards Staff, Transport Directorate in Seattle, Washington.

Since 1997 he has been assigned project management duties for the FAA's Nonstructural Aging Systems Project which will be addressing a White House commission on aviation safety and security recommendations regarding aging aircraft systems.

He has worked in the area of Transport Category Airplanes Certification since 1990, and prior to joining the FAA in 1990 he worked at Lockheed, Boeing and Jet Propulsion Laboratories. His education includes a Masters and Ph.D. in Electrical Engineering from the University of California in Los Angeles.

Now I will turn the microphone over to Mr. Robert Swaim.

MR. SWAIM: Thank you, Mr. Dickinson. Airplanes are designed to an economic design life, and with close monitoring and preventative maintenance the airline industry has been able to re-define what that design life can be and extend the number of years that airplanes remain in service.

Extensive programs in this area have been developed through close coordination between the manufacturers, the airlines, especially through their airline association, the ATA, and the FAA.

The Safety Board examined the subject of aging airplanes after an April 28th, 1988 accident involving Aloha Airlines Flight 243. The NTSB document on that is publicly accessible and it is report number NTSB AAR-89/03.

The accident investigation raised safety issues pertaining to maintenance programs and FAA surveillance of those programs. The accident became a catalyst for major changes in how aging airplanes are inspected and maintained, but the focus of most aging airplane programs is on the structure and not on the airplane systems which we have been talking about here.

Many of the potential ignition sources seen in the previous panel may be age related. I certainly had some people here yesterday talking to me after the Ignition Sources Panel about just that subject.

This panel will be addressing aging aircraft from two general perspectives. First we will be discussing what the regulatory requirements are for the continuing airworthiness of aging airplanes. After an FAA description of what the regulatory requirements are, we have Boeing, the manufacturer, who can present an overview of what the aging aircraft programs are and the history of how these programs have evolved, especially since the Aloha accident.

We would like to discuss the impact that these programs have on the airlines who operate these airplanes, and we would then like to change the direction and ask some questions and examine how the airplanes are actually aging in service, take some case histories.

Transport airplanes are extremely complex and have numerous redundant systems, so we would like to briefly discuss, once we are done with all of that, how the airplanes are dispatched with some non-conformances in some of these complex and redundant systems.

My first question is for Dr. Dunn of the FAA. Dr. Dunn, what are the regulatory requirements for airplanes that are operated beyond the original economic design life?

WITNESS DUNN: Well, Robert, primarily what you are referring to here is continuing airworthiness. When you talk about continuing airworthiness there is a role played in that activity by the FAA, the operator and the manufacturer.

As it relates specifically to the FAA, there is a – excuse me -- flight standards function which relates to FAA requirements that are given in Part 121, and Bill Crow is here to represent maintenance aspects.

The other aspect of the continuing airworthiness that the FAA addresses are in the design requirements which are found in Part 25, the airworthiness design requirements that the FAA levies on the manufacturer of the aircraft.

In that regard we have Part 25. I believe it is 1529, which basically says that the manufacturer must provide instructions for airworthiness. This is pretty simple, and basically it amounts to the providing of maintenance instructions.

I will read in part what some of those things are: recommended periods at which various appliances and parts should be cleaned, inspected, adjusted, tested and lubricated; the degree of inspections necessary and applicable wear tolerances. In addition, the applicant must include an inspection program that includes frequency and extent of the inspections necessary to provide for continued airworthiness.

That is basically the Part 25 design requirement which must be satisfied by the manufacturer.

MR. SWAIM: Okay, thank you very much.

Mr. Vannoy represents Boeing and, as Mr. Dickinson indicated, has extensive experience as far as these aging aircraft programs from the manufacturer.

So, Mr. Vannoy, can you kind of summarize these aging aircraft programs as Boeing sees them?

WITNESS VANNOY: Yes, Mr. Swaim, I will attempt to do that. Mr. Chairman, I have about ten pages of work charts and some comments on the general background and development of aging programs, and hopefully that will further our discussion and answer a lot of questions.

CHAIRMAN HALL: Yes, please, we would like to see them.

WITNESS VANNOY: Today I am going to provide a brief overview of the development and status of aging airplane programs. My comments are specifically directed towards the 747 airplane, but similar comments would apply to other Boeing models.

As far as some general background, around 1980 the industry became concerned over the general concept of airplane operation beyond original design service objectives. Maintaining safety was the prime consideration and has always been the prime consideration on the aging programs.

When the 747 was first designed in the late 60's commercial airplanes had previously become obsolete before twenty years. By the early 80's it was apparent that this would no longer be the case. The initial major concern was over fatigue cracking, and the first formal aging program addressed that issue.

In contrast to that concern, systems on the airplane provide indication when they fail, and Boeing has been monitoring service data on systems performance related to aging from the beginning.

Next chart, please.

(Slide shown.)

Here, I would like to emphasize that the aging programs have been going on for a long time. We have always had informal reviews of airplane structures and systems to observe airplane performance. We were always interested in how our product is performing in the field, and we have been proactive to go out and collect that data.

(Next slide shown.)

All these programs listed here, beginning in 1983 to 1988 were in place prior to the first 747's reaching twenty years of age which happened in 1990. Each of the four items or programs discussed here will be separately discussed later in the presentation.

All these efforts have been focused on assuring continued safety. I want to make that point. They have not been focused on making the airplanes last longer. The economic issues are worked in separate ways .

As of today, many 747's have exceeded original design service objectives. On my next page I am going to provide some details relating to that. We maintain that with appropriate maintenance there is no specific life limit on the 747 airplanes; however, it needs to be clearly understood that the aging airplanes do require increased maintenance and repair activities for operation beyond their original design service objectives.

(Next slide shown.)

I would like to provide some meaningful numbers related to the 747 fleet. Our design service objective for the 747 has been 20 years, 20,000 flight cycles -- and a flight cycle is one take-off and landing -- and 60,000 hours.

Airplanes and service that have exceeded those objectives are approximately 380 airplanes that have exceeded 60,000 hours, and of those approximately 240 are over twenty years old, and approximately ninety-five have exceeded 20,000 flight cycles.

MR. SWAIM: Where did the accident airplane fit in that range?

WITNESS VANNOY: The accident airplane was around 90,000 hours and 18,000 flight cycles.

MR. SWAIM: Twenty-five years old?

WITNESS VANNOY: It was twenty–five years old. I want to emphasize that all these airplanes are the classic 747's which are the 100's, 200's and 300's. There were some references, estimates made previously here about the number of classics operating today.

Boeing produced a little over 700 of the classic airplanes. Today there are about 620, I believe, still operating. We have also -- over the last ten years we have been building the 400 model. There are about 420 of those in service.

The first 747 entered service twenty-eight years ago this month. Since then the 747 fleet has logged 12 million flights and 54 million hours. Of the 1,140 747's that we have produced to date, several are no longer in service, including approximately thirty that have been disassembled and scrapped for economic reasons. So, our design service objectives did set an economic goal, and we are finding that there are a considerable number of airplanes that are no longer economic.

None of these airplanes were condemned or considered unsafe. They were removed from service for economic reasons.

Next chart, please.

(Next slide shown.)

The most well-known aging program on the 747 is the supplemental structural inspection requirements for a document. This is known as the SSID, or SSID Program. This was the first developed to address aging on the earlier models.

The 747 documentation was first released in 1983 following a development process involving the airlines and the FAA. The inspection requirements identified in this document insures timely detection of fatigue damage by requiring detailed inspections of the highest cycle airplanes.

The SSID Program utilizes a sample fleet containing some of the highest cycle airplanes. Since we are looking at fatigue damage we are interested in flight cycles, so the airplanes with the highest number of flight cycles are put in this candidate fleet.

Over the years this sample fleet has typically consisted of around 120 airplanes. We have received some reports of cracking. The program has worked adequately. It is still relied on today. When we do get reports of cracking, that particular item becomes an inspection requirement for the remainder of the fleet.

CHAIRMAN HALL: Now -- well, could you give us an idea of what cracking is?

WITNESS VANNOY: Well, when you talk about fatigue cracking, it is actually -- you know, the part is beginning to break open at some point. Usually, fatigue cracks are found in the early stages when they are very small, maybe a tenth of an inch, or -- it depends on the type of structure you are looking at, whether it is a lug or a piece of skin that is rivetted together.

But, we are looking for very small cracks, many of them by non-destructive test means, finding them in the very earliest stages and then preparing maintenance recommendations and programs to address them in the rest of the fleet.

MR. SWAIM: But, you are talking about structure here, right?

WITNESS VANNOY: We are talking about purely structures here.

MR. SWAIM: Okay, and this is redundant structure?

WITNESS VANNOY: This is all redundant structure, that is correct, and we are looking for the -- we are looking at the oldest airplanes, the ones with the highest cycles trying to find the first onset of cracking. This program covers hundreds of areas on the airplane.

My next comment here, so far in this program we have found twenty areas on the airplane where cracking did occur, and that has resulted in inspection requirements for the rest of the fleet. That has been communicated to the airlines by Service Bulletin, and the FAA has mandated those requirements by Airworthiness Directive.

MR. SWAIM: Without getting into work cards and specific inspection steps and so forth like that, in general how do you approach that? Do you simply collect records from the airlines, do you send out teams to work with the airlines and do you have target areas that you go after?

WITNESS VANNOY: Well, when you are talking about this particular inspection program, it only applies to the candidate –– or, the sample airplanes. SO, the airlines that have those airplanes have the requirements to do this additional inspection after having maintenance checks. It is an additional burden on them.

They specifically go in and look at these items per the requirements in the document. When they find a discrepancy they have to -- per the Airworthiness Directive they have to report it to us.

We report it to the FAA and begin putting together maintenance recommendations for the rest of the fleet so that this item will be addressed on the other airplanes.

MR. SWAIM: Okay, I guess I am trying to get a little more basic than that. How do the airlines with these airplanes know where to look?

WITNESS VANNOY: Okay, the document provided under this program tells them specifically which pieces of structure. It gives them zone diagrams, very specific directions and alternatives to reach the goals established in the program.

MR. SWAIM: That document comes from the manufacturer?

WITNESS VANNOY: It comes from us.

MR. SWAIM: Okay, thank you.

WITNESS VANNOY: This is a very specific program, but it is typical of other inspection requirements that may appear in either the Service Bulletins or other maintenance information.

DR. LOEB: Excuse me. This program, though, was set up based on the service history that had existed prior to that, and areas of concern that had been identified during the service history of the airplane, is that correct?

WITNESS VANNOY: Dr. Loeb, this program was established over a concern really for fatigue cracking, and it was really set up by the changes in the regulatory rules for new airplanes that came out in 1978 under FAR 25-571, I believe.

SO, we had to go back on the 747 and do a very detailed analysis, damage tolerance type approach, and identify all the areas where fatigue cracking would be a concern. It was a very large effort. It involved operators and the FAA.

We produced the requirements, worked with them to make sure that our inspection methods and frequencies were workable within the industry. So, this program was really established -- and the FAA started off by an Advisory Circular that kind of told US, you know, "this is how we want you to do it," and then when we produced the document they came back and, you know, put their Airworthiness Directive on it and made it mandatory.

DR. LOEB: Okay, thank you.

MR. SWAIM: Okay, I interrupted your presentation there, your slides.

WITNESS VANNOY: Okay, back to the slide. Just one more comment as far as the process we have been discussing. As far as finding problems early in the fleet and putting out maintenance recommendations, you know, this activity also occurs in the systems arena.

Whenever we find a problem having a safety implication on a systems item, we work it in exactly the same manner, with early detection provide maintenance recommendations, and it could also result in an Airworthiness Directive, and there is quite a few examples of that happening.

The next item I would like to discuss is purely a Boeing program that was established in 1986 called a Fleet Survey Program. At that time, we were concerned over the lack of data that we had, and there was a general concern over, you know, what were the effects of aging on our older airplanes.

We took a very proactive approach with the attitude that if there were problems or something wrong we wanted to be the first to know. So, we started sending out Boeing teams of six people or more, observing airplanes and heavy maintenance checks.

These people would go out and spend approximately a week on the airplane that was in a heavy maintenance check, and they had with them all the information, the service history, and in particular they would look for all known or suspected problems, but also do a general surveillance of the airplane as time and access permitted. During that program, which is still going on today, the operator cooperation has always been excellent.

Just a personal note; I participated in quite a few of these fleet surveys and I was generally the smallest person on the team and so I was nominated to do all the fuel tanks, and even the horizontal stabilizer tank. So, from yesterday's discussion I have had quite a bit of experience crawling around in fuel tanks.

In this program we have three basic goals. We were interested in the actual condition of the structure and the systems components, we wanted to make sure that our maintenance publications were adequate and, finally, we have always been interested in getting the lessons learned on our airplane so we can incorporate that into our new design activities.

Turn the page, please.

(Next slide shown.)

During this time we have looked at forty-two of the 747 airplanes. These have always been the oldest, highest time airplanes we could find at the time. So, that constitutes a pretty good percentage of the older fleet.

General comments about what we found; the findings in general have indicated that the airplane condition of both structures and systems is good, and the maintenance that we have observed has been excellent. This has been a worldwide effort. We have been to every continent, and a pretty good cross section of all our fleet.

We have had some significant results from this fleet survey. Some of the first Section 41 cracking problems, severe problems, were found by a Boeing team early on on this activity. I think Section 41 is probably the most well-known problem -- structure problem relating to the older 747's.

During our survey --

CHAIRMAN HALL: Could you elaborate just a little on that at some point, because I received -- we have received a bit of correspondence on that, and I would like –– you know, I think for the record it would be good to have some information on that and what Boeing has done.

WITNESS VANNOY: Yeah, the Section 41 cracking is basically frame –– internal frame cracking, problems that showed up about 1986. We had some multiple frames that were cracked.

CHAIRMAN HALL: Could we put a 747 up so

someone could point to Section 41?

WITNESS VANNOY: Well, if you look at the older airplanes and you are familiar with the upper deck and the three windows on the older airplanes, it is the section right in front of and underneath the three windows on the upper deck and, you know, right behind the flight -- where the flight crew sits.

It is the nose of the airplane, and it has kind of a flat part of -- the side of the airplane is flat up there, and that is the forward part of the airplane, the Section 41.

MR. WILDEY: Mr. Chairman, I would point out that the Section 41/42 joint is at the very forward end of the reconstructed airplane. So, that is the start of the Section 41, just in front of the reconstruction.

CHAIRMAN HALL: Thank you.

WITNESS VANNOY: SO, in 1986 when we became aware of this concern over the multiple cracking, we acted very quickly, we shared our information with the FAA and the airlines by -- I think within two or three days we had some maintenance information out and the FAA put out a telegraphic Airworthiness Directive to do a quick inspection of the airplane.

Within about two weeks we developed an extensive Service Bulletin for internal inspections, identified the requirements' initial inspection threshold, repeat intervals, we had multiple operator meetings to convey all this and I think the original requirement was for airplanes over 15,000 cycles that had to be inspected quite quickly.

That still carries out today. Those inspections are still enforced today, maintaining safety in the older 747's. We realized we needed to make a design change, so we changed our design and implemented that in 1987, I believe, at about line position 680.

Then, the Aging Aircraft Task Group came along a few years later and included that retrofit requirement as one of the mandatory modifications in aging airplane programs. So, airplanes as they exceed 20,000 flight cycles, they must have this mandatory modification. Up until that time, they must do the repetitive and internal inspections.

So, the program has worked very well and we have --

CHAIRMAN HALL: The accident aircraft had or had not had this?

WITNESS VANNOY: The accident aircraft was subject to inspections, and it had repeat inspections at 13,000 and 16,000 cycles, and it would have been due for another at 19,000. So, it had accumulated 18–plus thousand cycles.

CHAIRMAN HALL: But, it did not have the retrofit because it was not over 20,000 cycles?

WITNESS VANNOY: It didn’t have the retrofit because the operator had chosen not to apply that yet. But, I think the findings indicated that the cracking was as we would have expected. It was very minimal.

MR. SWAIM: A matter of clarification. You used the term “NDT.” What does NDT stand for? What is it?

WITNESS VANNOY: Mr. Swaim, NDT is non-destructive testing, which could include x–ray, ultrasonic -- different techniques that we use in the industry today to look for cracking in the structure.

MR. SWAIM: Okay, thank you. Mr. Chairman, if I could add one further point, these areas on the accident airplane were examined in great detail because it was a known problem, and there was no evidence of any kind of fatigue cracking in that area. There is no report on that, by the way.

CHAIRMAN HALL: Thank you. I just think it is important for the record that it be pointed out that it was looked at very carefully as part of the investigation.

WITNESS VANNOY: Okay, as I was saying, we found some Section 41 cracking -- in our surveys, we have also found some significant findings related to systems. None of those have impacted safety. We have addressed those with maintenance recommendations.

We have also, in addition to the fleet surveys, continued to take other opportunities to go out to airline visits and look at systems.

If I could have the next chart, please?

(Next slide shown.)

MR. WILDEY: Mr. Vannoy, before you leave this area, can you compare the fleet survey airplanes with the candidate fleet of airplanes under the SSID document? Are they the same airplanes?

WITNESS VANNOY: Many of the airplanes would be the same airplanes. It is the same basic goal. In both cases we are looking for the oldest airplanes, and the SSID airplanes, the candidate airplanes are the ones generally above 20,000 flight cycles, and those are the ones we are also seeking out in survey programs. So, many of them are the same airplanes.

CHAIRMAN HALL: Mr. Vannoy, you mentioned that as you found system problems they have been addressed through recommendations, or Service Bulletins?

WITNESS VANNOY: That’s right.

CHAIRMAN HALL: Do you know how many of those there have been, and have there been any in regard to the electrical system of the 747?

WITNESS VANNOY: I checked through a lot of databases and results of the fleet surveys. I did not find anything relating to the electrical systems. An example of what we found; I know we found some corrosion on the landing gear actuator that resulted in some improved maintenance recommendations.

But, generally we are doing visual checks, and even though we –– you know, we look at wire bundles and we looked at everything on the airplane we could. There was very little found from this survey activity that would relate to any wiring or general systems problems.

CHAIRMAN HALL: So I am clear for the record, were you looking for those problems, or were you just looking at structural problems and as you -- maybe system – a system problem came to your attention, that was addressed, or were you looking for both?

WITNESS VANNOY: We were looking for both. We had systems specialists on our team, and they basically looked over the whole airplane; you know, everything from cable runs to door systems and cockpit and anything they could look at.

CHAIRMAN HALL: Please continue.

WITNESS VANNOY: Okay. The reports that we were receiving from the fleet surveys and from the airlines, Section 41 and other fuselage structures in the mid–80's convinced us that additional data was needed.

In 1987 Boeing acquired a 747-100 airplane that had accumulated 20,000 flight cycles in service, and we put that next to our factory and set up a test fixture.

Over a two and a half year period the body structure was subjected to an additional 20,000 simulated flight cycles. From this activity we developed a detailed fuselage inspection program that was defined for the fleet and published by an Alert Service Bulletin. An alert designation on a Service Bulletin designates a higher priority bulletin, typically signifying safety implications.

The threshold for beginning this inspection was set at 22,000 cycles, which is about ten percent over our design service objective. We had extensive operator meetings concerning this to explain what we had found and what the requirements were going to be for these older airplanes.

This is quite an extensive inspection requirement that is on top of normal maintenance. So, when the airplane gets to 22,000 cycles there is a lot of extra work that has to be done here to satisfy this requirement .

CHAIRMAN HALL: But, just on the structure?

WITNESS VANNOY: The structure.

CHAIRMAN HALL: Could I ask, just when this program -- and I have had the very nice –– went out to Seattle and saw this -- saw your airplane out there. Is there any reason that you all did not look at all the systems as well as the structure when you went through the 747–100 and did this program?

WITNESS VANNOY: There wasn’t any specific reason. I guess at that time we were really focused on the structure and had urgent need to do that. So, there wasn’t any real time established, or --

CHAIRMAN HALL: So, I guess -- what was the Aloha accident, in ’80 ––

WITNESS VANNOY: That was ’88.

CHAIRMAN HALL: ’88, all right.

WITNESS VANNOY: So, just to note, to date we have had about forty airplanes in the fleet that have gone through this inspection, as defined by this bulletin and Airworthiness Directive.

After we made the re-design on Section 41 and some production changes, we did -- right beside that test airplane, we did do also a test of a new 747 forward body section to validate our design and retrofit changes.

Next chart, please.

(Next slide shown.)

Now, following the Aloha 737 accident in the spring of 1988, new concerns were raised. The FAA sponsored an international conference on aging airplanes in June of 1988 and directed the formation of industry working groups.

Groups were formed for structures non-destructive testing and propulsion. The Structures Group was the most active group, and the real objective there and the new concern was we had to take a new approach and we had to come up with methods that would consider the combination of fatigue in the presence of other damage.

MR. RODRIGUES: May I interrupt a second. Bob, there is the wrong slide up for this part.

WITNESS VANNOY: Thank you, Dennis, I didn't notice.

(Next slide shown.)

Sorry for the confusion there. The real

objective coming out of this was to find a new approach where we could consider a combination of corrosion in the presence of other damage such as fatigue. Previous to this, corrosion and fatigue and whatever was kind of considered on an isolated basis. We had to take a new approach to be able to consider the combination of corrosion effects.

Out of these programs that the Structures Group developed -- they are all listed here, and there is actually six items. I am not planning to discuss all of them in detail, or even mention some of them.

They are pretty well known in the Structures community, but the most notable of these programs is the Corrosion Prevention and Control Program, and that provided minimum requirements for inspection and repair. Today it addresses all in-service airplanes. So, that has had a tremendous impact on airplane maintenance.

These industry actions initiated in 1988 to address aging safety concerns have demonstrated a cooperative determination to make the right things happen throughout the industry.

Just a side comment, the detailed examination that was conducted of the accident airplane, the twenty-five year old accident airplane, and the lack of any significant corrosion or cracking does provide additional confidence that the programs are working.

The Structures programs, as well as any other programs undertaken in this arena, are under the oversight of the Airworthiness Assurance Working Group, AAWG, which is sponsored by the FAA.

DR. LOEB: Before you continue, these programs, including the original SSIP that started in ’83 and then all these others were not specific to the 747, is that correct?

WITNESS VANNOY: That’s right.

DR. LOEB: They were fleet-wide across all airplanes and --

WITNESS VANNOY: That is correct, Dr. Loeb. As I indicated originally, my comments here are specific to the 747, but the programs -- industry programs apply to all the older airplanes; Boeing models and other manufacturers, as well.

DR. LOEB: Your fleet surveys were also across your models?

WITNESS VANNOY: That is correct. In our fleet survey activity I think we have looked at over 200 airplanes in total.

DR. LOEB: Thank you.

WITNESS VANNOY: I have been in a position over the last fifteen years to review all the incoming data from the fleet, and it has become very evident to me that since these programs were established about ten years ago, you know, the number of aging airplanes have exceeded our design objectives, have exceeded -- you know, they have gone way up, but the serious reports that we have been receiving have gone way down.

So, it is very obvious to me, as somebody in a position to review all this data, that it has been very effective, and it is generally considered a good success story and one that all of us in the industry are very proud to have taken part in.

Okay, I have discussed the Structures story, but I would like to make a few comments about systems. Systems performance is continually monitored throughout the operation of the airplane. Systems design provides multiple levels of redundancy.

Systems faults are apparent to performance and built-in monitors, and during scheduled maintenance systems go through additional functional checking, and components are replaced, if necessary.

I think these general comments kind of sum up why we haven't had specific programs dedicated within the industry to collect additional data on systems.

(Tape change.)

Within Boeing we have been proactive in seeking out information on aging effects on systems. The airlines do provide reports to us as they identify potential problems. We have monitored in-service data, and that allows us to detect problems or trends in early stages and provide maintenance recommendations in a timely manner.

We have taken part in fleet surveys to try and find anything related to systems that would be a concern. One example of where we did use the surveys to provide some maintenance recommendations was in a service letter which we produced in January of 1995 that provided a lot of maintenance recommendations in relation to wiring on high time airplanes.

This service letter, at the time it was produced, did not include any wiring recommendations inside the center wing tank. It was all airplane wiring in the body wings.

CHAIRMAN HALL: Is there an economic design life for wire?

WITNESS VANNOY: No, we haven't established any life. Basically, the design requirements on wire that we designed the airplane to and test and certify are the wiring should last as long as the airplane does.

We are committed to design, build and support safe and reliable airplanes. I want to emphasize the word “support.” Over a thousand engineers are totally dedicated within Boeing to daily support our in-service fleet. They have no other job responsibilities. In addition, we have several hundred engineers in customer service organization that are on site throughout the world at the airlines.

As problems are identified we take action, and safety concerns receive our highest priority. Only incoming information is reviewed more or less on a daily basis, and safety items are keyed, and we have a very robust process, not only of reporting items to the FAA, but working internally for that priority. That is basically a continuing airworthiness approach.

Just a few comments in closing. This is my last slide.

(Next slide shown.)

I am not up here in a defensive position trying to say that we know it all or we have done the work on aging airplanes totally. There is still much work ahead, and one thing that needs to be emphasized is existing programs that have been established are ongoing and they are all subject to continual review and updates.

The task groups meet periodically. We had a meeting earlier this year on the 747. We are continuing our Fleet Survey Program. We recently surveyed a domestic 747 that was delivered in 1970. We hold operator conferences for communication and working together efforts.

Every year for the last nine years we have hosted regional aging airplane conferences around the world inviting operators, regulatory agencies and all those associated with maintenance. We recently conducted a major 747 conference in September. We have established some working teams.

I think we discussed in previous days here the All Model Fuels Issues Team that -- the working group that has started looking at things like bonding and grounding. We have also established some airline working teams to improve dispatch reliability in systems areas. So, Boeing remains open. We are committed to future participation in any program to improve safety.

As a final comment, I would like to say that I believe the best solutions will again come through the collective efforts of our industry, relying on facts and data and working together. Thank you. That ends my --

CHAIRMAN HALL: That is an excellent statement, Mr. Vannoy. Would you mind explaining for the -- for us what an on condition failure is?

WITNESS VANNOY: Well, many systems components on the airplane are subject to on condition maintenance, and that means, basically, when the item ceases to operate, or a circuit breaker trips, or the function isn't there anymore, then it receives attention and it gets replaced or maintained.

so, it probably means that that item is not subject to what we call hard time maintenance which -- alternatively which would say that at a particular interval you would pull it off regardless of whether it is functioning or not functioning.

On condition means you leave it on the airplane until it indicates it is not functioning anymore.

CHAIRMAN HALL: Does Boeing -- does this apply to most of the systems in the aircraft, if not all, or do you have --

WITNESS VANNOY: That is correct, Mr. Chairman, it would. Our maintenance recommendations in the maintenance planning document put virtually all the systems in the on condition category. There is almost nothing that is -- from the Boeing standpoint, that is hard time now.

In the airline world –– and we could hear from maybe our TWA representative -- but, in the airline world in their program of continuous airworthiness they do monitor reliability, and when they establish reliability information on components to maintain the reliability and, you know, success on the airplane, they do establish times when they pull items off and overhaul them regardless of whether they work or not.

Certainly that is common today, and most airlines have those programs where many items are pulled off at certain intervals, whatever 20,000 or 40,000 hours, whatever they establish for their own requirements .

WITNESS DUNN: Mr. Chairman?

CHAIRMAN HALL: Yes, one -- yes. Just one last comment, and then I will –– or, who –– where did the voice come from?

WITNESS DUNN: Mr. Chairman, I --

CHAIRMAN HALL: Oh, I am sorry, at the end of the table. I apologize.

WITNESS DUNN: If it would help, I can give you the definition that is actually in an FAA-AC Advisory Circular.

CHAIRMAN HALL: That would be good.

WITNESS DUNN: Okay, first of all I will talk about what the definition is of hard time limit. Now, understand I am not a maintenance person, but I am reading the actual definition from the Advisory Circular.

"Hard time limit is a maximum interval for performing a maintenance task. These intervals usually apply to overhaul, but are also applied to total life of parts or units."

Now let's talk about on condition. On condition does not mean fly 'til failure. That is something that I think we need to be very clear about. It doesn't mean you don't do maintenance until there is a failure.

What it means is it refers to maintenance done in regards to repetitive inspections or tests to determine the condition of units, or systems, or portions of structure. So, it refers to a repetitive inspection process. You don't wait until something fails to take action. Hopefully that clears up the --

CHAIRMAN HALL: Do you consider the wire bundles and wiring be part of that systems that you just referred to from the FAA regs?

WITNESS DUNN: Yes, it would be, but I think a more complete answer could be given by our maintenance representative. Mr. Crow could perhaps elaborate on that.

WITNESS CROW: Would you like me to do that, Mr. Chairman?

CHAIRMAN HALL: Yes, sir, please.

WITNESS CROW: There are three --

CHAIRMAN HALL: And let me just say that -- so, again, state for the record, we do not know what caused the TWA 800 tragedy. One of the factors that has been widely reported and one that is considered is the age of the aircraft. It was twenty-five years old, and I think we -- or, we need to look into these issues and be sure that we understand.

I appreciate Mr. Vannoy pointing out a very aggressive program that Boeing has had over the years in the structure area. Obviously, what the Chairman is going to be getting to is, is there any reason that we need to be doing that in the systems area.

We have looked extensively at what was referred to yesterday as a derelict aircraft, that where we found that our inspectors found most of the problems weren't visually available. They were underneath connectors and et cetera.

I guess the question is, with the information we are getting out of this investigation whether or not this has anything to do with the tragedy of TWA 800. I know the industry and the FAA are as interested, if not more interested than the NTSB in getting all the safety lessons we can out of an investigation that has gone into the detail this one has.

SO, that is where I am coming from, Mr. Crow. SO, I think any information you can put on the record on what is presently being done and what we just discussed, it would be helpful.

WITNESS CROW: All right, sir, I will be happy to do that. I am going to call on Dr. Dunn and also go back to his definitions in the Advisory Circular, and he will –– when I share this information with you, he will know exactly where I am going with that. If he doesn't, I will lean over and help him.

There are three basic maintenance processes within the air transportation industry. One of them is hard times, one is condition monitor and the other one is on condition. Those three particular processes are really identified in the reliability programs that are evident in most of the major air carriers today.

One of the things that I would like to cover ––

CHAIRMAN HALL: That word "most," is that --

do you mean all, or do you mean most?

WITNESS CROW: No, sir, I do not mean all, and I am trying to choose my words very carefully because the reliability program is not a mandatory requirement of the FAR. It is, if you will, a privilege that allows an air carrier to develop its own reliability processes for the purposes of extending appropriately the intervals between inspection and changing of components.

CHAIRMAN HALL: Well, does TWA have a program?

WITNESS CROW: I believe they do, sir.

CHAIRMAN HALL: Yeah. So, I wanted to be -- 1 didn't want to leave the opinion that they did not have a program. Mr. Craycraft, you are probably going to speak to that later, is that correct?

MR. CRAYCRAFT: Yes, sir, we do.

CHAIRMAN HALL: Thank you. Please go ahead, Mr. Crow.

WITNESS CROW: For the record, let me say this right up front. I don't present myself as a Boeing 747 expert, or an expert on TWA. My comments and my speaking are purely on behalf of flight standards service, and in some cases that I will identify as my opinion, as a supervisory aviation safety inspector.

CHAIRMAN HALL: All of us are just here trying to provide as much information we can in this investigation to advance safety, and I noticed –– I didn’t -- Mr. Craycraft, how many years of experience do you have in the aviation industry?

MR. CRAYCRAFT: Forty-one.

CHAIRMAN HALL: Well, I noticed there were 182 years of experience, and I didn’t have your 41, so there is clearly well over 200 years of experience with this panel in the aviation industry, and –– so, that is why I want to listen very closely to everything you gentlemen have to say. Please proceed.

WITNESS CROW: For the record I would like to have my colleague, Dr. Dunn, read the definitions of those three maintenance processes. Again, he has all ready read the hard time definition to you, and the on condition definition. I would like for him to read one more, which is the culmination of the three processes, condition monitor.

WITNESS DUNN: Fortunately, I have also got that available for me. Condition monitoring; “For items that have neither hard time limits, nor on condition maintenance as their primary maintenance process, condition monitoring is accomplished by appropriate means available to an operator for finding and resolving problem areas. These means range from notices of unusual problems through special analysis of unit performance."

WITNESS CROW: I would like to continue by saying I think, if I am correct, Bob Swaim is going to ask me some questions here in a moment, and I do have -- not a prepared, if you will, presentation, but I will cover a lot of these things in order to try to close the circle regarding continued airworthiness requirements on air transport category aircraft on behalf of the Flight Standards Service.

MR. SWAIM: Sir, where we intended to go with this was to get the basics from Dr. Dunn with the FAA of here is what is legally required, in general, and then have Mr. Vannoy tell us basically where we have been over the last ten years or so, what these aging programs are in fairly general terms.

My intent next was to go to Mr. Craycraft. As he said, he has got forty-one years with TWA, and to ask him how the -- you see, we are narrowing down the cone here -- how does TWA as a representative airline implement all this guidance and help they are getting from the FAA and Boeing.

That is where, Chairman Hall, if --

CHAIRMAN HALL: No, that is fine. Please proceed.

MR. SWAIM: Okay. Mr. Craycraft, here is my question. How do you implement all of this as far as maintenance programs? You have to tie it into your maintenance programs. How do you take care of these older airplanes?

WITNESS CRAYCRAFT: Well, the programs described by Mr. Vannoy and others is accomplished at TWA with a continuous airworthiness maintenance program. It is all under that large umbrella.

The continuous airworthiness maintenance program includes all of the FAA mandatory program requirements and is identified in our operations specification manual that is approved by the FAA.

The maintenance program incorporates the aid of a maintenance alert computer system that tracks all the scheduled maintenance requirements on each aircraft and provides alerts to our operational planning department so that they can schedule the aircraft to a TWA maintenance station to accomplish the required maintenance sections.

We have a couple of other programs. The Maintenance Operations Control System is a computer program that does this tracking and alerting for the scheduled maintenance.

We have -- we are loaded with acronyms, as everybody is. We have an AMPS system, an Aircraft Maintenance Planning System that tracks and provides control for aircraft log book remarks, non-routine maintenance items, follow-ups to log remarks and call-out requirements for special maintenance activities.

We have a Maintenance Coordinating function that is on duty twenty-four hours a day that provides a continuous overview of all of our maintenance activity. To support that we have an engineering staff that is on duty at normal engineering hours, but are available on call at any time to provide technical assistance or advice to the maintenance organization. That is where I fit in the organization. I have had many late hour phone calls.

This is the way the program is identified, and we - 1 have a copy of the 747-100 operations spec here in front of me that is about an inch thick, on both pages that identify these items that were described as hard time items, on condition items, conditioned monitored items and things of that sort.

Then we further expand on the on condition. There are some items which we can perform a detailed test on the airplane, so we will call that an on condition on the aircraft, or we have some that we feel that we cannot adequately perform the test on the airplane, so we call that an on condition shop item.

We will remove the item, send it to the overhaul shop and the appropriate tests are accomplished and determined whether it is operating within its specifications, or not.

MR. SWAIM: Okay. Mr. Vannoy talked about these aging aircraft programs and Boeing requirements. Mr. Craycraft, how far -- well, let me rephrase that. Do you follow the Boeing recommendations as far as aging maintenance maintenance and these –– is it like with my car that I can follow the maintenance manual, but I don’t really have to?

WITNESS CRAYCRAFT: No, sir. This -- the Aging Aircraft Program in TWA was very active with Boeing and the other air frame manufacturers in developing the structural requirements and the detail requirements that is involved in the aging aircraft activity, as well as the Corrosion Control and Protection Program.

So, we -- and many of those items are mandated by AD once they are identified by the Aging Aircraft Program, and we certainly follow the AD requirements .

MR. SWAIM: Okay. Now, do you do most of your own maintenance, or are you like some other airlines where you contract out most of your maintenance?

WITNESS CRAYCRAFT: This particular maintenance we are speaking of here is accomplished by our own mechanics, as Mr. Liddell would be glad to support.

MR. SWAIM: Good point. We have the IAM here.

Mr. Dunn -- Dr. Dunn, is this in excess, beyond what the regulations are calling for? Is this in addition to the regulations?

WITNESS DUNN: I can't what --

MR. SWAIM: I am not asking you to -- you know, sir, do they comply. I am just saying, from what he describes are they beyond -- are they in addition to what the basic regulations call for?

WITNESS DUNN: This is an area that I can't really describe, because you are talking about specifically the operator's maintenance program

MR. SWAIM: Okay.

WITNESS DUNN: That is really an issue for Flight Standards to address.

MR. SWAIM: Well, before we go there, Mr.

Crow, is that something that you feel comfortable saying, whether you feel they are doing what the regulations comply, or more?

CHAIRMAN HALL: Of course your question is specifically regarding TWA?

MR. SWAIM: Yeah, do they do more than the regulations require?

WITNESS CROW: I think that all of our U.S. certificated air carriers exceed the minimum requirements of the FAR in the work that they do for continued airworthiness. I have in the past had opportunity -- limited opportunity to spend some time with the Trans World Airlines organization in Kansas City and St. Louis, and our findings were that they were doing the -- were meeting the minimum requirements of the FAR and in many cases exceeding those.

MR. SWAIM: Okay. Mr. Craycraft, as an operator again, okay? - since you are doing your own maintenance, do you do maintenance on other people's, other operator's airplanes coming in?

WITNESS CRAYCRAFT: It is a contract operation. We have done some and at different times do, yes.

MR. SWAIM: Okay. My next question is, how do you compare your airplanes with ones that are coming off maintenance from other places?

WITNESS CRAYCRAFT: Usually the contract operation that we perform on other operator's, those airplanes are incorporated in our maintenance program and that is the way that we repair and maintain their airplanes, as if it were a part of our own maintenance program.

MR. SWAIM: Right, but when it comes in to you from somewhere else, as you receive the airplane in equivalent period in its life to your own airplanes, are they as well maintained as yours, are they as clean as yours, those kinds of questions?

WITNESS CRAYCRAFT: I don't work on the floor, so I really can't answer that question, Bob.

MR. SWAIM: Okay. I am getting a little ahead of myself. I would like to go back into the structural area again. One of our specialist metallurgists is Mr. Jim Wildey who worked on the Aloha accident, and I would like to see if Mr. Wildey has any questions at this point as far as the structures.

MR. WILDEY: I don't have any right now, Bob. I think I will save some for a little bit later.

MR. SWAIM: Okay, very good.

Mr. Craycraft, there is a large feeling amongst the mechanics and pilots in the industry that with deregulation and more competition in the airlines that the airlines are tighter on their maintenance and possibly even cutting back some.

What is the cost? Well, let's go back a step. Is it a competitive industry?

WITNESS CRAYCRAFT: I think that is fairly obvious.

MR. SWAIM: Okay, and what is the cost of doing this kind of maintenance on these airplanes to keep up an older airplane?

WITNESS CRAYCRAFT: I do not know any specific cost or man-hours involved in a heavy maintenance check.

MR. SWAIM: Mr. Vannoy, can you speak to that?

WITNESS VANNOY: Yes, Mr. Swaim, I could give you some general numbers. First of all, there has been some discussion previously here about things like C&D checks and what is scheduled maintenance. I would like to kind of try and put that in perspective.

The typical airline, let's say operating an older 747, would do their scheduled maintenance in the form of what we call A-checks, C-checks and D-checks. The A-check would be a fairly frequent maintenance opportunity that would be maybe one day down time every month.

The C-check would be more or less a yearly inspection which would be about a week, or a little more down time per year. Then the D-check would be the heavy maintenance which comes approximately five years, and it would be a month or more down time.

SO, those are the scheduled maintenance opportunities for a typical operator as one day a month, one week a year and a month every five years. Other than that, the airplanes are subject to line maintenance, which is whatever can be done in between flights.

SO, I hope that gives a little better perspective. The cost of heavy maintenance on the 747, let's say a D-check where you would have the airplane for a month or more, as the airplane, the older airplanes have gone beyond the twenty–year threshold, that cost has gone way up.

You might have as much as 30,000 or more man hours to do a heavy maintenance when the airplane is, say, fifteen years old. But, when it gets up to twenty-five years old with these additional requirements put on by the task groups, that number could double or triple.

SO, we are talking about a lot of man hours.

It is a very big airplane, a lot of surface, a lot of access. The Corrosion Program that was identified for the 747; if you were to take an airplane and you needed to do all that activity on the airplane to, let's say, baseline it, the estimate was 25,000 man hours just to do all the access, the inspection and the restoration of all the panels and everything you need to do. That is just to accomplish the Corrosion Program that was identified and mandated in 1990.

SO, I hope that provides some perspective on maintenance .

MR. SWAIM: Yes, sir, thank you. We found a cooling tube missing from a fuel pump that we examined during this investigation. We went into manufacturer's records and we found a couple of prior instances of that.

The cooling tube in the fuel pump also acts as a flame arrester. Now, in testing we found there is a check valve.

CHAIRMAN HALL: Mr. Swaim, are we -- do we have anymore presentations from the panel, or are we just getting into questions?

MR. SWAIM: We are getting into questions.

CHAIRMAN HALL: Well, could I --

DR. LOEB: I thought you were going to get some information on the record from Mr. Crow that would have helped to set the context and an understanding, that you were going to ask some questions of Mr. Crow. Mr. Crow, in fact, I believe indicated that he was going to be getting some questions from you that --

CHAIRMAN HALL: Well, we seem to be wandering here. Let's take a break for fifteen minutes and see if we can't get our train of thought together. Off the record.

(Whereupon, a brief recess was taken.)

CHAIRMAN HALL: On the record. We will reconvene this hearing of the National Transportation Safety Board. I would ask the observers to please take their seats. We are in the -- on agenda item eight of our hearing, which is the Aging Aircraft Panel.

We are now going to continue with the questioning by the Technical Panel, and I will turn it back to Mr. Swaim.

MR. SWAIM: Thank you, sir. Where we are trying to go with this is to look at the Aging Airplane Programs that have been set up specifically as far as structure, dividing the ideas of structure an systems, and develop what has happened in structure and then go and look at the equivalents in systems, if there are any.

so, with that, Mr. Wildey?

CHAIRMAN HALL: Let me just say what the Chairman -- what the prerogative of the Chair is. There are two other things that I would like the panel to address, and then obviously -- and those are -- number one is what interface is there -- since Boeing manufactures both military and commercial aircraft, Mr. Slenski and the military has spent a great deal of time looking at the issues, and I am sure you are familiar with his report.

What interface is there at the government level and the industry level so the military experience and the commercial experience, if there are safety lessons to be learned we can benefit. Maybe that is already in place, but I would like to hear more about that.

We also need to discuss the particular maintenance on the -- on the aircraft accident -- the accident aircraft so that we have a full discussion of the issues. Once again, clearly understanding that none of these items at this time -- we have any reason to know that they were the probable cause of this accident.

We do not know that, but we are trying to discuss everything in a methodical way that has been done as part of this investigation to try and determine the cause of the accident. So, please proceed, Mr. Swaim.

MR. WILDEY: Yes. Mr. Vannoy, I would like to ask you to just provide us a little bit more background, if you could, on the history of the development of the methodologies of looking at how to maintain airworthiness for the structure.

Could you give us a little bit more background on the methods of doing this, such as fail safe, safe life, and then eventual development of the damage tolerance philosophy, please?

WITNESS VANNOY: Okay, I will do my best, Mr. Wildey. The 747 was certified initially under regulations at that time which was a fail-safe approach which required redundancy, but the amount of analysis to substantiate that was fairly minimal.

In 1978 the regulations changed to the damage tolerance approach under FAR 25-571 and, as I stated in my presentation, the SSID Program required us to go back on those older airplanes and do extensive re-analysis of the airplane under the new rules which did a damage tolerance or crack growth approach, considering a crack beginning anywhere in the structure, even when the service history and the loads didn't indicate it was likely to begin.

Again, we had to consider all the alternatives through very extensive crack growth studies and predict how long the structure would survive under various scenarios. That led us into the requirement for the SSID Program and more or less put the 747 on the same basis as the newer models, 5-7 and 6-7.

SO, that required combinations of visual techniques, ultrasonic inspections and identified many requirements on the airplane, and I think I covered that pretty well in my discussion on the SSID Program.

so, as we -- so, that kind of covers that, but in general, as we develop a structures problem in a -- and identify some maintenance recommendation for it, on any individual item we may provide recommendations to the operator giving them thresholds, intervals, guidance.

It may be fairly complex and it may be fairly simple, depending on the structure, the access required and what it takes to find the crack in the very early stages.

DR. LOEB: Excuse me, Jim, for one second. Mr. Vannoy, do you know what it was that led to the change and to the damage tolerance concept, what occurred that led to that?

WITNESS VANNOY: Well, I think it was a combination of new technology and just trying to do a better job in general. I think the CAA was instrumental in pushing that, but within the industry we developed the techniques to do the crack growth analysis. We didn't have those methods in the 60's and, so, it was a new concept.

But, the damage tolerance approach involves a lot more work up front from the analysis side, but it also incorporates those requirements into the maintenance program so that for a particular piece of structure you identify what the opportunities are to find a crack, and you have to work the inspections of your maintenance program to conform with that. So, you will have those opportunities.

So, the airline working group is putting together the maintenance planning for a model to have the results of analytical information available to them, and they have to develop the maintenance program to give those opportunities to the operator. So, it goes hand in hand for analysis, design and the maintenance program.

DR. LOEB: Thank you. Jim, go ahead.

MR. WILDEY: Are you familiar with the

classification of fuselage skin as damage obvious or amount function evident that was pre-Aloha era for the purposes of doing the damage tolerance types of inspections?

WITNESS VANNOY: On fuselage skin where we considered the cracking would lead to depressurization and what we call flapping of the skin?

MR. WILDEY: Yes.

WITNESS VANNOY: Yes, I am.

MR. WILDEY: I guess the question here would be, after the Aloha accident it was obvious that this classification was eliminated and the fuselage skin was then incorporated into the SSID Program as far as it being more -- it was then had to be inspected on a routine basis.

Do you think that this type of philosophy at this time seems warranted for systems types of things, or where we have possible latent failures?

WITNESS VANNOY: I am certainly aware of the change on the structures side that led to, you know, putting more structure and putting skin laps into the SSID Program. I am not sure that is a good analogy to use on systems.

I think in my discussions I covered some of the attributes of systems that they have, you know, that are designed specifically for redundancy and to annunciate a failure. The system design testing and the certification we go through is supposed to consider, you know, all the potential latent effects that could exist on systems, and we did a very thorough approach.

So, latent failures in systems is something we basically can't tolerate and we -- when we identify those items to further analysis, service history, or whatever, we go in an eliminate them with a design change and a Service Bulletin, and we have many examples on the 747 where systems changes have been implemented on airplanes as a mandatory -- you know, because they were latent.

Now, I think the approach we are in today is that we are going out and being more proactive and looking for latent failures that we haven't seen before, or haven't contemplated. I think, you know, the Fuels Issues Task Group is doing that in the fuels area to look in grounding and bonding which can be a latent failure. We are taking steps in that area in fuels.

The Gore Commission is pushing us towards doing some similar studies in the aging wiring area to potentially look for latent failures. I think Dr. Dunn is actively involved with the FAA on those proposals, working with Boeing. Maybe he could add some to my comments here about what that program is going to do specifically, looking for latent failures that we haven't considered or found it for.

MR. WILDEY: This is a good opportunity for Dr. Dunn. I know you are assigned to respond to the Gore Commission's recommendations. Can you address those?

WITNESS DUNN: Yes, I can. Actually, I am the Project Manager for those activities within the Aircraft Certification Service.

What we are doing is –– I believe it was about February of this year that the White House Commission on Safety and Security made a Recommendation 1-9 that the -- that aging aircraft systems be incorporated into the Structural Aging Aircraft Program, the one we have heard described previously.

So, the task that we have put together is to address that recommendation, and the White House Commission has expressed a concern in the general area of aging systems, as well as the public. I have received comments from various individuals expressing their concern about aging aircraft systems, as well as professionals in the field.

SO, what we have done is we have put together a program to –– we have put a program in place where in June of next year, June 1998, we expect to have the FAA's recommendations regarding aging aircraft systems ready for the Administrator.

DR. LOEB: Do you contemplate a program along the lines similar to or modelled after the SSIP Program for structures for the systems area?

WITNESS DUNN: The intent is that by June of next year that we will be in a position to make those recommendations . What we are doing currently is just going out, and we are going out into the field, and we are looking at our processes to see if our processes that we have in place regarding design approvals and continuing airworthiness are adequate.

SO, in that regard what we are doing is we are going out and we are going to actually look at some of the same fleet, aircraft that are in the current Aging Aircraft Program.

CHAIRMAN HALL: Can I -- can I ask for a clarification of one thing? When we talk about systems, is a wire a system?

WITNESS DUNN: No, a wire is -- would not be considered a system.

CHAIRMAN HALL: What about a wire bundle?

WITNESS DUNN: No, it would be –– a wire bundle and wires --

CHAIRMAN HALL: What does Boeing consider the 150 miles of wire in a 747? Do you have a -- you know, just wire, or is it part of a system, or ––

WITNESS VANNOY: All wiring is parts. The wire constitutes a part of the system material. It supplies the energy or the indicating –– but, it is part of a system.

CHAIRMAN HALL: It is part of the electrical system of the airplane?

WITNESS VANNOY: That is correct.

CHAIRMAN HALL: No?

WITNESS DUNN: Well, no, not necessarily.

CHAIRMAN HALL: I just -- you know, if we are looking at systems, I -- and we are talking about wiring and we have got – we have had some discussion about wiring. I am trying to understand from a layman’s standpoint where does the wire fit into the system?

WITNESS DUNN: Mr. Thomas, I think, can add to this.

WITNESS THOMAS: Yeah, let me try a little, Mr. Chairman.

CHAIRMAN HALL: Then I believe Dr. Dunn wants to pop in, too, Mr. Thomas, but please proceed.

WITNESS THOMAS: I was just -- from my viewpoint, the airplane has numerous systems on board. They have hydraulic systems, fuel systems, electrical systems, air conditioning systems.

We use a large percentage of this 150 miles of wire to transfer energy and information around the airplane. So, a given wire bundle, or a piece of a wire bundle –– the FQIS one is the one we have used a lot -- would be part of the FQIS system and therefore part of the fuel system.

But, power, feeder lines, they come from the engine or just part of the power systems, or any wire on board the airplane is going to be considered to be part of a system. So, when you talk system you automatically include all the wiring in the airplane.

CHAIRMAN HALL: Where all those wires run together that I described yesterday, and they are bundled together, do you look at the impact of one system on another, or in terms of failure?

MR. SWAIM: I think that would be a question really for Mr. Taylor. Mr. Taylor is a specialist in wiring and has been with Boeing for many years.

WITNESS TAYLOR: The answer to that question is absolutely. Each system analysis takes into account the fact that the wires in that system have been run in a wire bundle with wires from another system, and if there is any contention or feeling there can be interplay between them that a separation of that wire -- these wires for the system into another wire bundle, the assignment of wires into wire bundles is a result of a system analysis which makes sure that those which need to be separated are separated.

There are various degrees of separation for different kinds of threats which then allows the wires to be put in a bundle where they will not be affected by that threat.

CHAIRMAN HALL: And you do a -- one of those fault tree analysis, or whatever we were talking about yesterday?

WITNESS TAYLOR: Yes, systems analysis people do them.

CHAIRMAN HALL: SO, if you assume that the wire was frayed or became corrosive or abrasive, you would look at the impact of one wire?

WITNESS TAYLOR: Open circuit, a short circuit, what would the impact of that be in the system and the other wires in that bundle. If it would offend any of them, then it is placed in another wire bundle so that it will not have any affect on them.

I think if you think of your body, and as a person you think of your veins and your arteries which connect your various subsystems, the veins and the arteries that are like the wire --

CHAIRMAN HALL: Well, I think, Mr. Taylor, that is why most Americans are concerned about the subject of aging aircraft, because they all have aging systems. I know mine is. I have to -- it costs me a lot more to maintain it now than it did.

SO, I think that is why it is a concept the American people can understand, and I think I just want to -- I think what we are trying to grasp here is what has been done about it in the past, and maybe what we are doing and what has been done in the past is adequate.

But, are there any things -- as we all know that there is the fleet. The statistics show that we are going to have older - a larger number of the fleet will be older airplanes. So, what is being done?

Mr. Vannoy did a very good job of laying out what is being done in the structures area, and I guess obviously now what is in systems. Do you think additional things need to be done in wiring, or are you looking at other things from a Boeing perspective?

Since you are the electrical and wiring

expert, as your fleet gets older are there other things that you think would be -- you would recommend, or would be –– Boeing would be looking at?

MR. TAYLOR: The answer to your first question about do you think there are things that should be done in wiring. It has been our philosophy in Boeing that we should always be looking at the wiring to see what we could do to make the wiring better.

We understand that the wiring is not perfect. We have done an enormous amount of research to try and put the best wire that we can get onto the airplane, but we also understand the fact that the airplane environment may have some affect on the wire that we haven't understood at that point in time.

SO, we are continuously looking at wire bundles in the aircraft to see how they are behaving, what is happening, and then that is fed back so that when we come to the design of the next airplane we take that into account.

CHAIRMAN HALL: Thank you. I will let Dr. Dunn comment, and then I will turn it back to Dr. Loeb. I apologize.

WITNESS DUNN: Yeah, I -- the only thing I can say is there are some –– there are regulatory requirements which do –– which actually are given that insist that the manufacturer look at the interactions of systems. So, it relates to wire bundles where you have more than one system in the same bundle wire, if you will.

They are required -- there are regulatory requirements to look at the interference and possibly interactions and failures between those various systems.

DR. LOEB: In developing this program that you are looking at and developing now for aging systems, is wiring going to be an inherent part of that effort?

WITNESS DUNN: I am glad you asked, Dr. Loeb. We are going to look at all systems, and all systems is basically anything outside the primary structure which was the focus of attention under the previous Structural Aging Aircraft Program.

Systems would be things like pumps, valves, wiring. Actually, I would refer to these more as components, if you will. Tubing, landing gear, engines; these are all considered in the context of the study as systems.

DR. LOEB: SO, it will include wiring?

WITNESS DUNN: Yes, most definitely.

DR. LOEB: Right, now – and I think the point I would -- I would like to explore a bit is the kinds of things that Mr. Vannoy pointed out, and I think it was the second to the last graph that you had put up, the AD’s, ESB’S, all of the things that are done when you find systems problems.

All of those things were done when we found structures problems that pre–dated when –– before the SSIP came into existence and then before the changes that occurred after Aloha.

SO, I recognize that there are programs to address problems that arise in the systems area, but there were also programs that were there to address problems that arose structurally prior to the SSIP.

Nevertheless, at some point, because of experience, because of history, it was determined that a program specifically to address aging airplanes, airplanes that were -- that were going to live beyond their design service life was needed to be done, and part of that program was to identify the critical items, those items in which you could have a catastrophic failure if they weren’t addressed properly and so forth.

I guess, Mr. Dunn, my question is, is this what we are going to do in the systems area, something similar to that? After Aloha, even though there was this very excellent program, the SSIP Program that had existed for many years prior to Aloha, that the FAA did ask as a result of the task force and so forth for the manufacturers to go back and re-evaluate all of the structural components of the airplane, to re-examine and determine whether new critical components needed to be addressed and so forth, and there were a number of AD's that resulted from that.

My question is, are we doing something like that in the development of this program to address aging systems?

WITNESS DUNN: What we are doing in order to come to this plan that we want to put together by June of next year, and a set of recommendations associated with that plan, is to look at our processes, see if we have adequate processes in place, look at the way we do maintenance, look at the way we -- the tools our maintenance people have, the training they have.

As we have mentioned earlier, we have a continuing airworthiness program which is there to address aging systems, if you will. However, we are not sure that we have all the answers and that we -- we want to make sure our processes are adequate, because it relates specifically to an exact outline of a program that you mentioned for the structural. We are not there yet.

DR. LOEB: Yeah, my point is that there was always a continuous airworthiness –– a continuing airworthiness program that existed for structure.

WITNESS DUNN: We have had continuing airworthiness programs, and you have to keep the airplanes airworthy. Nevertheless, there was this enormous development that went into this program that addressed structure, and after Aloha combined corrosion and fatigue.

We recognize there is a continuing airworthiness program for systems. The question now is these systems are -- as they age, we are learning some things about them just like we learned about the structure.

MR. SWAIM: Is that kind of learning process that we went through in the structural area going to be applied to systems, or are we just not going to learn to use what we have already learned in the past?

WITNESS DUNN: Again, what we are going to do is spend this year to look at it –– look at the scope of our problem and our policies and procedures. At that point, then we will decide whether a program akin to the structural program is needed.

CHAIRMAN HALL: Okay, let’s proceed, Mr. Wildey.

MR. WILDEY: Yes, my thought at this time would be to ask some of the other panel members if they have any comments on this subject. Mr. Slenski, do you have any insight you might add in terms of what the military might be doing on this?

WITNESS SLENSKI: Well, there is two approaches I can take here. I can talk generally, or the presentation I did have was talking about wiring failure mechanisms, and I will show you field failures and how wire fails.

CHAIRMAN HALL: Well, why don’t you give us both approaches.

WITNESS SLENSKI: But, maybe we need to do that first, if that is okay, because I think once I show that, I think it will be a little more obvious in my other comments. So, I guess we can get the first slide up here.

(Slide shown.)

This basically was a request to discuss wiring and cable failure mechanisms in aircraft, and this was actually a presentation I did recently. Just this, again, says where do we fit in this and how did we get involved?

Basically, I am a failure analyst. I get the components into the lab and we analyze it and provide recommendations back to the users and operators of the systems. So, first --

(Next slide shown.)

The next chart here we will get into more detail . This is the -- what we call wiring the system. We go out to procure an aircraft, we will have a trait study done possibly on the type of wire insulation selected, how the wiring is installed in the aircraft, and I think at this point we do consider it to be a system in itself because it has become so important, and that now we do have fly-by-wire aircraft and the wiring is a -- the failure of wiring in some situations can affect the operation of the aircraft in flight. so, it has become more of a critical system.

Take a look at the upper left there for a moment (indicating) . This is typical wiring in a fighter aircraft. If you could zoom in on that?

(Next slide shown.)

As you can see, there is quite a bit of wiring moving back and forth in there in that aircraft. There is -- these bundles are almost like tree trunks in the aircraft, and one of the problems of inspection is every time you disturb that bundle you can induce more damage.

That is -- a problem we run into is how much inspection do you want to do on good wire, because in the process of inspecting it you can cause more damage in that process.

If we go to the lower right corner, this is interesting. This is wiring out of an aircraft that had been retired that is actually sitting in the desert in Arizona. If we zoom in on that, this is one of the problems with wiring.

(Next slide shown.)

Some of that wiring is actually saturated with hydraulic fluid, so the wiring sometimes lives in fairly severe environments. We talk about aging problems and fluids. We do design wire to be exposed to all types of fluids; hydraulic fluid, jet fuel, water, and we do run tests to determine how long wires can live or survive in these types of environments.

This is just an example of this. You do see these types of fluids on wires, and they may exist for quite a long time on the aircraft. So, that is how we approach, as far as the Air Force.

We do consider the system and we do realize wire is exposed to fluids. We actually have tests to determine how long wires can last in these environments when we make determinations for the aircraft.

Typically, the aircraft wiring age is tied to the air frame, and when we replace wiring typically it is more for upgrades. Avionics, or electronics in the aircraft, as you are aware, change rapidly. Many times we go in there and replace wire because of upgrades and modifications .

DR. LOEB: Have you determined in these -- in your looking at these issues at any time where wiring was deteriorating in a shorter period of time than the life of the airplane and made specific changes as a result?

WITNESS SLENSKI: Yes, and I will show you the example in the next slide on that. If we can have the next slide, please?

(Next slide shown.)

Since we mentioned that, if we go to the lower right corner. This is an example of wiring, and this was due to chemical degradation that occurred fairly prematurely in the life of this system.

Basically the wire was exposed to alkaline materials, and these are basic solutions, and that actually attacked the insulation ans degraded its mechanical properties, and we had cracking and arcing from that situation.

That was -- basically, in this situation gun gas is in the aircraft for getting near the wire, forming potassium hydroxide, and that was attacking the insulation which in this case was polyamide, and it is a known problem that polyamides and high alkaline cleaners and various compounds will degrade the properties of that material. This is a situation where we found that, and we have taken corrective actions.

If we could go up to the upper right (indicating). I think this is an interesting example, and this is an inspection. Actually, I was on some aircraft where we found a broken wire–exposed conductor during an inspection.

Typically, when we are looking at wiring and you get into this inspection issue, most of your damage is within about six to twelve inches of your connector, and why that happens is because that is where most of the maintenance is performed where you are moving large boxes of avionics out, or you are moving the wire bundles.

That is the type of wire that would see the most of the damage, because most of our studies have shown chaffing. Mechanical damage causes most of our problems to our wiring.

What is interesting here to note is you have got this exposed conductor there. However, that wire is perfectly happy to sit there until there is a mechanism to cause a leakage current and -- or a short. To make that happen, another wire next to it has to have an exposed conductor, or that exposed conductor has to come in contact with the structure.

That can be intimate contact, or through a conductive solution that may form between that wire and another conductive surface. So, this is an example where actually this wire could go until its life and never have a problem, as long as another wire, or there is an opportunity for a path to complete this electrical circuit here.

DR. LOEB: So, that requires multiple failures for something untoward to happen?

WITNESS SLENSKI: That is correct.

DR. LOEB: However, one of them, or two failures, could be latent for a long period of time resulting in only one failure at that point, creating a problem?

WITNESS SLENSKI: That is correct, and that is the difficulty, I think, as we -- say, developing these aging programs, is when do you take action when you are having these types of issues come up? But, this is an example of the --

CHAIRMAN HALL: Mr. Slenski, does the Air Force have a life span for a wire?

WITNESS SLENSKI: Currently, our life span of wire is the air frame, but we do continuously monitor wiring, look for -- what I would -- the word I think I would like to use here is wiring integrity. We try to maintain the wire integrity.

If that requires inspection programs, anti-chaff programs, awareness –– because, again, a lot of times the wiring problems we are seeing are chaff related due to handling during maintenance or have maybe even been during initial installation.

We try to make sure the people working on the aircraft and maintenance troops are aware of wiring problems, how the wire fails. They could look for these types of damage sites during normal maintenance of avionics.

Typically, again, you are not going to get in there and disturb the wires. When you may see it, though, is when you are removing other avionics for either modification or repair. You need to go ahead and look at the wiring at the same time to see if there is any problem areas. So, we ask people to do an overall inspection when they are in the area of the aircraft.

DR. LOEB: But, right now the Air Force treats wiring essentially like the commercial counterpart, and that is for the aging -- for the life of the airplane they assume the wiring will be okay?

WITNESS SLENSKI: In most cases, but the reality is as we upgrade our systems we may actually require -- actually replace complete wire bundles in a system more for upgrade purposes than because we have a degradation problem.

But, our instances where if we see a problem we will actually replace the wire in the aircraft, and there are programs like that going on today.

DR. LOEB: Mr. Slenski, what is an average age for an Air Force airplane, or what do you consider an older airplane?

WITNESS SLENSKI: That can be quite considerable in age, but that is an interesting question because the earlier photo I showed you was from some of our fighters that have been retired with around 7,000 hours of flight time, and they were fifteen to twenty years old.

However, we have got cargo aircraft and transport tankers that are well over thirty, forty years old, obviously, in the fleet, such as B-52's. That is a fairly old aircraft, and we are going to be flying those aircraft for quite some time.

There are fairly aggressive programs, as we have heard from Boeing, to maintain these systems and look for reliability issues and upgrade the systems and maintain all systems' bonding.

Maybe I can even answer one of the questions yesterday. You asked about quality programs that we instituted. After having discussion on the phone this morning, where that came out of, we had some incidents on the KC–135, some wiring related problems associated with the fuel system.

As a result of that we now have phase inspection of the wiring in that area, and we are actually going in there checking bonding measurements occasionally. There is a phase -- there is actually a formal process for that now. So, depending on the system, each system has its own unique requirements.

DR. LOEB: Okay, do you --

CHAIRMAN HALL: That KC-135, is that a Boeing aircraft?

WITNESS SLENSKI: That is correct.

MR. SWAIM: Do you find your older transport, or B–42's, or whatever, are they up in the same time zone hours of flight as our higher time civilian airplanes?

WITNESS SLENSKI: I don’t think anywhere near it. Obviously, the military flies different types of missions, so we have no where near the flight hours on our aircraft. Obviously, it is more the physical age. Chronological age, I should say.

SO, as an example, I was mentioning those fighters only had 7,000 hours on them over a fifteen, or twenty year period. That is actual flight hours, so most of the life of a lot of the aircraft is sitting on the ground, possibly in alert status.

MR. SWAIM: Sitting on the ground they go through regular -- like block-up grades, and can you explain maybe a little of the depot or block–up grade type --

WITNESS SLENSKI: Every aircraft does have phase inspections where I think, as Boeing pointed out earlier, there is different inspection phases, and I am not an expert in that area, but I do know we send –- there is maintenance done in the field and in -- every so – so many years and, again, it is system specific.

The aircraft will be sent back to a depot for more major overhaul on all systems. I can’t give you that detail. I am sure I can find that information if you need that, but it will be by per system, depending on the type of aircraft.

CHAIRMAN HALL: Mr. Wildey, either Mr. Taylor, or could Mr. Slenski address this subject of what type of wire was on the accident aircraft and what wiring is now used in commercial aviation?

MR. WILDEY: I think Mr. Taylor would be most appropriate for that.

WITNESS TAYLOR: On the TWA accident aircraft, the type of wiring was a wire commonly referred to as polyex. It is -- and the Boeing specification number for that is BMS–1342. BMS stands for Boeing Materials Specification, and 13 indicates it is an electrical material. That was the general purpose wire used throughout the aircraft.

When you go into the design of a new aircraft, one of the things you want to do is try and select a general purpose wire which will be used as much as possible throughout the aircraft and serve all the needs of the majority of systems, and then the special systems get special purpose wire.

The general purpose wire usually constitutes about ninety percent of the wiring in the aircraft. That wire is selected -- we go to that product to select a wire which will meet the requirements of most of the systems so that we minimize the differences in processes that wire bundle assemblers and maintenance people will have and, you know, reduce the number of tools that they will have to have in order to make the wire bundles and to service the aircraft.

The fewer processes they have to deal with, the fewer changes of tools they have to do, the better the job they will do and the more reliable will be the wire harness. So, that is why we attempt to use one wire type to satisfy the needs of all the systems.

CHAIRMAN HALL: Is that the same wire still used on the 400 series?

WITNESS TAYLOR: No, the wire that we use in the 400 series is a totally different wire. It has a different chemical composition and it is a BMS-1348 which is a cross-link ethylene -- tetrofluoroethylene insulation system, and we have had that wire on the 747 for many, many years now. It has been an excellent performer.

CHAIRMAN HALL: Why did you change from the polyex to that wire?

WITNESS TAYLOR: The reason we changed from polyex was because the manufacturer of polyex stopped manufacturing it. One of the polymers that were necessary to make the insulation was no longer made and they discontinued it.

MR. WILDEY: Mr. Slenski, I know that you have a couple more view graphs to show me, and you will be getting into types of damage to the different kinds of wire. When we get to anything that can apply to polyex, would you please point that out?

WITNESS SLENSKI: I will point that out to you. If we can go back to the --

MR. WILDEY: Mr. Slenski, may I interrupt? Before you continue, you mentioned that the Air Force has a program to monitor the wire -- condition of the wires. Could YOU -- is this just a visual inspection, or what is the program to monitor the wires?

WITNESS SLENSKI: As I said, this time it is pretty much a visual inspection, although there are some attempts where you can electrically make measurements if the aircraft is back at the depot where you can actually disconnect a connector, you could put a device on there to make leakage current measurements to see if you have a short in a wire bundle at some location. But, that typically would only be done at a depot.

Now, we are looking at programs that we call non-destructive inspection that allow us to find some faults in wiring, and there are several programs out there that are attempting to do this. I will discuss one of those in a few moments here, and we can show a chart on that on what we are actually trying to do with wiring.

MR. WILDEY: Before we leave the view graph that you have got up there now, though, this is a defect in the insulation of the wire. The wire itself is intact. Would something like this be detectable if it wasn't visible to someone who just happened, maybe, to see this?

WITNESS SLENSKI: This would not be because, again, the wire - as long as it is electrically still -- there is integrity there as long as there is no leakage current there, and obviously you have to be able to see this and expect that it would have to be exposed.

There are techniques out there, though, that can find this type of damage, and I will show you an example of that here in a few moments. They can actually detect this type of a problem very easily.

MR. WILDEY: Thank you.

MR. SWAIM: Before we leave this, you mentioned the Air Force has an anti-chaff program, and my question is, is that the same as your on condition maintenance?

WITNESS SLENSKI: It is a little bit different. If you recall, one of the images I had shown in a previous slide was off a fighter. In very small airplanes, quite a bit of wire packed in those aircraft. There is tight spaces. There is more opportunity for chaffing and movement of wire bundles.

So, in our smaller aircraft we have more aggressive anti–chaff programs than in a transport that has much more space on it, so to speak, for wiring.

MR. SWAIM: Okay, so I would like to go back to Mr. Taylor representing the manufacturer. The 7-4 is a big airplane, but it has got a lot of tight spaces. Do you have an anti-chaff program set up for the 747?

WITNESS TAYLOR: We do not have a program that is specifically titled "anti-chaff." First of all, we address the chaffing issue mainly in the design. Chaffing begins in the design.

If you design the aircraft properly and you make the wire bundles properly and you install them properly, put clamps in the right places, put the right kind of clamps in place with the right spacing, tie the bundles correctly, then you will minimize the opportunity for chaffing to occur.

So, that is the first area where we think that the attention should be placed.

CHAIRMAN HALL: What is your service history, Mr. Taylor, over the thirty years in regard to chaffing? Is that -- have you found evidence of chaffing being a problem?

WITNESS TAYLOR: We have had evidence of chaffing. In fact, if you -- if one were to look at the service letter that Mr. Vannoy referred to, we went out and we looked at various 747's throughout the world, inspected them.

We cited incidents of chaffing that had occurred and we then put it into a service letter and sent it to all the airlines with ample illustrations showing what was occurring and giving them –– giving them not instructions, but telling them what they should be looking for and what they should do to improve it.

We did have a chaffing problem on the 747-100 with polyex in the initial installation. The polyex wire was the first wire where we had gone from insulation systems like PVC, which are soft like boiled spaghetti, and we went to polyex wire which is a thin insulation for weight–saving –– one of the reasons we did it was because of the constant pressure on all systems people to minimize the weight of the system.

For weight saving purposes we went to a smaller insulation system, a lighter insulation system, and in order to get the same characteristics in the life of the wire, it is a –– it is a tougher material. It is harder, and initially when we changed over we used the same installation techniques that we used for the softer wire.

The polyex wire has -- 1 think a banjo string may be a good analogue to the polyex wire versus the softer wire. As a result, when we installed it we didn't notice when we put it on, and when we put it on in high vibration areas we did get chaffing. That occurred after about 5,000 to 10,000 hours of service life.

Immediately we got reports back from the airline operators that we were getting a succession of chaffing problems on the leading edge of the wing and on the struts. We put together a program where we analyzed what would happen and came up with a re–design.

We put together kits. We sent out a Service Bulletin to all the airlines alerting them to what was going on. So, we had kits put together and sent them the whole kit so that they could re-wire the -- re-wire the airplanes.

Now, in these kits we used a different kind of clamp. We changed the tie string spacing. We just changed the installation so that we –– it was compatible with the type of wiring that we were now using. This was a learning experience which we and others went through.

Once we learned that, then we incorporated it in the wiring design from then on. So, we are constantly improving the wire design so that we can take care of changes in technology as they come along.

CHAIRMAN HALL: I assume that Service Bulletin became an AD?

WITNESS TAYLOR: I don't know whether -- I think the --

CHAIRMAN HALL: Dr. Dunn, do you know if -- or, Mr. Crow, whether that ––

MR. SWAIM: I am aware of a chaffing AD that we had on some of the fuel system wiring.

CHAIRMAN HALL: Well, if we could find out and provide that for the record, I would appreciate it.

WITNESS TAYLOR: This was nothing to do with fuel service -- fuel system wiring. This was totally and distinctly complete from fuel system wire. So, that is really the only chaffing problem we have had that does not occur in a random type of pattern.

MR. RODRIGUES: Mr. Chairman, from the Boeing table?

CHAIRMAN HALL: Yes, sir.

MR. HUGHES: That Service Bulletin was not an AD.

CHAIRMAN HALL: It was not an AD?

MR. HUGHES: Correct.

CHAIRMAN HALL: Okay, thank you. Well, that is a very complete answer, Mr. Taylor, and one that was well understood. Thank you.

DR. LOEB: Before you -- just one additional question on the polyex, Mr. Taylor. Have you in your experience with polyex found other problems, other than this chaffing problem due to the vibration?

WITNESS TAYLOR: We have found that polyex has two other attributes that we preferred it not to have. One of them is the polyex wire is constructed -- it has a three-layers of material. The inner layer is about five thousandths of an inch thick of polyex material.

Then there is another layer about the same thickness, and then there is an outer layer which we call a top coat. It is white, and one of its purposes is so that we can put a mark on it that -- so that people can identify that wire bundle.

It is a unique wire for that -- sorry -- a unique mark for that wire. Every wire on the airplane has a unique identifier, and that is one of the purposes of that white top coat. We have found over the years that that top coat tends to separate from the outer layer and you get flaking occurring. That is one problem.

DR. LOEB: Is that because, you say, of the marking process?

WITNESS TAYLOR: It has nothing to do with the marking process. It is an adhesion problem between the top coat and the outer layer, and through time the adhesion -- it separates. That occurs randomly. It does not occur in large flakes, or anything like that. It is just randomly.

The second problem we have had is we have seen occurrences of cracks, radial cracks. If you were to take something like that an bend it (demonstrating), you would see a crack across it. We have seen occurrences of that. That, again, occurs on a random basis. It usually occurs in a place where there is a bend radius.

We try our best to utilize the space as best we can and make them -- keep the bend radius to a maximum and not to a minimum. We try not to just stuff it in there, but organize it so we that we use the best bend radius.

We have also seen it in some places where it is disconnected. The connector has been used to disconnect from equipment which is removed readily, or often just at the back of the connector.

DR. LOEB: These cracks are just through the top layer, or --

WITNESS TAYLOR: The cracks, depending on the amount of stress that has been put on them, can go through just that top coat. It can penetrate the outer coat, and sometimes there is evidence that they have penetrated the inner coat.

The design of the wire with the two layers of it is specifically designed so that if you stress the outer layer and it does crack, the crack will not propagate into the second layer. You will always have an insulation system.

The other thing about these cracks is that they -- even although the crack is there, they are very close. They are as close as my fingers together so that when they are in the aircraft, even though the wire is cracked there is no exposure of the conductor to a fragment of metal, or to any other piece of structure.

DR. LOEB: What about at bends, though? Have you found any of these cracks at bends where the wire is stressed where the insulators are --

WITNESS TAYLOR: I have not seen any like that. I have inspected 747's, I have looked at the leading edges of the wings which is a pretty severe environment, and the -- I saw on one airplane one crack just at the back of the connector.

It so happens this airplane was in service, and I was not about to disconnect that connector to detect whether or not the crack actually --

DR. LOEB: Is this cracking phenomenon in any way associated with aging, or just -- well, you know.

WITNESS TAYLOR: The cracking is associated with aging in a specific environment. If you have a humid -- not a humid, but an environment where you have a high Ph type of fluid and a tight bend radius, eventually the fluid will contribute to the cracking by the effect of hydrolysis as to loosen the bond between the molecules, and then eventually a crack will appear.

But, as I say, the crack is a line and not a gap.

DR. LOEB: Does your experience with a VMS-1348 show that it is a superior wiring to the polyex?

WITNESS TAYLOR: In terms of aging, it does not have any of the characteristics of the polyex. It does not have a top coat on it, for example. It has two layers, the same idea, so that any stresses on the outside will not be transferred into the inner layer.

The cross link tepsel is impervious to fluids and, so, we don't have this problem of hydrolytic attack by fluids. So, it is a better performer. It is an excellent wire.

CHAIRMAN HALL: Mr. Taylor, could I ask -- and let me be sure -- my understanding is on the accident aircraft that the polyex wire was used in wire runs adjacent to the center wing tank fuel quantity indication system wiring, and that polyex was used for the fuel pump wiring.

Did you do a failure analysis on that system?

WITNESS TAYLOR: I have not been involved in any of the failure analysis conducted on the TWA airplane.

CHAIRMAN HALL: Are you -- in your history with Boeing, are significant wiring bundle maintenance failures copied so they are reported to Boeing by the airlines and come up through the system that was described to us yesterday?

WITNESS TAYLOR: Yes, the wiring failures are reported. The most significant -- the effect of the failure, the more rapidly the failure is reported and the more rapidly something is done about it, as Mr.

Vannoy described.

Usually what happens is that when a wiring failure is reported, it is also reported back into our standards organization, and we will look at it and if we recognize it as being of a pattern we have seen before, we will add that to the list and we will already have done something to solve that problem.

If it is a new problem, the first thing we will do is ask the airline to send that particular piece of damaged wire to us so that we can make an analysis of it and then do something about corrective action if we need to do it.

One of the major problems is that if wire damage is discovered on an airplane which is in service, the necessity to get that airplane back in service overrides the attention of the mechanic to carefully store the wire and preserve the evidence so that he can send it -- he or she can send it back to us.

So, in many cases, we do not get the wire back and, so, we are unable to really do a proper failure analysis. But, in many cases we do.

CHAIRMAN HALL: I guess that leads me to the question, Dr. Dunn, in looking at the White House Commission's recommendation, are you going to be looking -- going out and physically inspecting the airplanes, or just looking at records?

WITNESS DUNN: No, sir. We are going to go out and physically look at the aircraft. We have systems engineers who will be accompanying us as well as maintenance personnel and research people within the FAA, as well as possibly, depending upon the area of interest, industry experts to help assist us in looking at the systems in the aircraft.

CHAIRMAN HALL: Thank you. Mr. Swaim? Oh, I am sorry, Mr. Crow and Mr. Slenski, you have comments? I am sorry.

WITNESS CROW: Yes, sir. For the record I would like to share some information that may be helpful to the Board. It may be helpful to the American people in understanding that there are two processes that are at work in the design and the operation of an aircraft.

One of them is the design criteria, and at the present time, as I have listened to our distinguished witnesses and others that have given testimony, most of the testimony that I have heard thus today is regarding design criteria and not continuous airworthiness requirements.

One of the things that I would like to offer to the Board for a full understanding of some of the problems that you are very interested in -- and we are in Flight Standards very interested in this also -- wiring; some of the largest concerns that we have in wiring are the events that occur during routine maintenance and the changing and modification of aircraft.

I would suggest to you, not as a Flight Standards opinion, but it is my opinion that most of the problems that we have regarding wiring are the results of two things, aging and foreign object intrusion such as hydraulic fuels, et cetera.

But, one of the other most probable causes of damage to wiring is the maintenance activity that does occur around them. One of the initiatives that we have in Flight Standards right now, as we speak we have a lot of the carriers that are installing smoke detection and fire suppression equipment in the cargo compartments.

One of the initiatives that we have in particular is standing side by side with our certificate holders watching the prototypes of those things going in, and one specific area of observation and concern is when we are working in close proximity to an existing wire bundle to make sure that those things do not have contraindications, one on another, and cause a chaffing concern.

Over the years -- and I share some experience with these other gentlemen. In forty years of aircraft maintenance in various levels of responsibility, I have noted often that it is the modification of aircraft and the maintenance of aircraft after the aircraft is delivered to the certificate holder, or to the Air Force in this case, that the damage to the wiring occurs as a routine thing, concomitant and existent with the maintenance activities in the modification of the airplane.

SO, I would suggest from a Flight Standards perspective that we spend an awful lot of time, as we are doing currently, looking at those modifications and looking at those things that do disrupt the wire bundles going through the airplanes. Thank you, sir.

CHAIRMAN HALL: Thank you. Mr. Craycraft, you have forty-one years of experience. What has been TWA’s experience with polyex and the wiring of the 747? Do you have anything you would want to share with us? I assume -- you have been a hands-on person, right?

WITNESS CRAYCRAFT: Yes, sir.

CHAIRMAN HALL: Yeah.

WITNESS CRAYCRAFT: The wiring on the 747 on the TWA fleet has not really been a continuing problem area. The odd time we would have an individual system that will have a chaffed wire, and oftentimes that is because of a broken clamp or something of that sort, that will allow a wire bundle to sag against structure and chaff.

The result there is either you get a false indication of a light in the cockpit, or a system will not work, or you will pop the circuit breaker, depending upon the extent to which the wire is contacting the structure.

Again, I say that has been most rare as far as the 747 is concerned, that we have not had the problems with the polyex wire. Our earlier airplanes were wired with a wire that was preceding polyex and some of the –– some of our aircraft do have the polyex.

I was with the NTSB team when we were at NASA Labs, and we observed some cracking of the insulation on the –– some of the wiring that was brought there. None of this was wiring that was in the fuel quantity system. That is an entirely different type of wire that is being used in the FQIS wiring.

so, any of the problems we are describing here do not relate to that in any way, shape, or form.

CHAIRMAN HALL: Could you tell us -- or, Mr.

Taylor tell us about the wire in the FQIS system so we know the difference.

WITNESS CRAYCRAFT: I will defer that to Mr. Taylor, since he is the wire expert.

DR. LOEB: Well, before you do, I would just like -- some of that polyex wire is routed, though, along with FQIS wiring; is that correct? I mean, FQIS wiring is routed in places in common with -- in the same wire bundles as polyex?

WITNESS CRAYCRAFT: There are some locations where they are in a common bundle, and there are other locations where the fuel quantity wiring is routed in a separate clamp away from the other bundles.

DR. LOEB: Right, thank you.

WITNESS CRAYCRAFT: But, what we received there at NASA Labs was a ball of wire wrapped up in a box, so who knows what was bundled next to what. But, none of the wire that we examined there showed any evidence whatsoever of arcing.

There was some cracking, but as Alex had described, the crack was just a minute crack circumferentially around the wire, and you had no loss of protection of that wire.

CHAIRMAN HALL: Thank you. Mr. Taylor, if you could explain the difference to us, and then we will go back to the Technical Panel, since --

WITNESS TAYLOR: Well, actually, this picture behind me illustrates the type of wire that is in the FQIS system. The conductors are – the conductors you see in the center are copper, they are silver plated.

The outside insulation you see is teflon, and teflon is -- you all know how well teflon does as a bearing surface, et cetera, et cetera. So, it is a very, very good insulator, it is extremely resistant to any kind of fluids and it is flexible, and it just makes a good wire.

The thickness of that insulation is fifteen thousandths of an inch. The size of the conductor, the overall gage size is twenty gage. Now, the -- that is a basic wire.

The FQIS wiring system consists of a cable which contains one or more of these wires. The type of system we were talking about yesterday usually has one single wire with a shield, a metal shelf over the top, a braided shield over the top of it, and then it can come –– and it is usually white. It then can come with one other wire in that harness which is red, or it can be blue, depending on the system design.

That, then, has an over-braid of a lacquered nylon which holds the whole thing together, and it makes a very substantial bundle.

CHAIRMAN HALL: Does teflon have an economic design life?

WITNESS TAYLOR: No. Let me rephrase that. I am talking fifty years, I am not talking two centuries or three centuries away from here. I am talking just within the realm of my lifetime, another fifty years.

CHAIRMAN HALL: All right. Thank you, Mr. Taylor. Mr. Swaim, are you or Mr. Wildey up?

MR. SWAIM: Today I will be Mr. Swaim. Mr. Slenski, I would like to go to you for just a second. We have been talking about small radial cracks and wiring. We have heard about this a couple times, cracks that go around the wire, possibly down to the conductor.

If it goes down to the conductor, but you can't see the conductor, is that okay, or is that ever a problem to have the conductor in that condition, especially -- excuse me, let me throw in one more part of that question.

We have found water based cleaning fluid residues in wiring areas in this airplane, so -- I am sorry, go ahead.

WITNESS SLENSKI: Once you have started a crack -- and this is referring to polyex now, or any insulation?

MR. SWAIM: Primarily in this accident polyex, but I would like more general.

WITNESS SLENSKI: I am not sure if I could speak. I don't know personally many of the properties of polyex, but as far as any insulation, once you have initiated a crack, there is always that potential that you can crack all the way through.

Now, it is typical with these insulations there is enough dielectric strength to withstand the voltage applied to them. As long as you have any insulation there at all you are probably not going to violate it. You actually have to get all the way down to the conductor, most likely, to actually have some type of arc event.

So, even if we got down to maybe even the inner third layer, as long as that has integrity you probably will be okay, but obviously any bit of flexing could take that further on down into the -- and expose the conductor.

We heard the explanation of three-layer construction for the idea that you will not propagate the crack through each layer, but if you have a bend in that insulation you do have stresses in those areas.

You can stretch these materials and they can initiate cracks.

SO, you know, once you have initiated cracks in there it is undesirable, but detectable. You are only going to see that again if you have an arc event, or visually you might see it, but it can be very difficult.

MR. SWAIM: But, if you do have this crack that goes all the way through and you have got a humid environment --

WITNESS SLENSKI: But, if you have conductive fluids, you know, you would almost have to have the conductive fluid in there, as Mr. Taylor was mentioning. Even if it is a fine crack, if you have fluids in there they can get down into that crack and you can set up what we call arc tracking, eventual wet arc tracking, where the fluid develops a conductive path between two surfaces, and over time you can actually initiate an arcing event.

SO, you need the conductive path in there somehow, and that could be a pieces of metal, it could be a fed, a piece of metal fiber, or a piece of -- a small piece of metal, or it could be the conductive solutions which we recognize are on all aircraft.

MR. SWAIM: Okay.

DR. LOEB: Let me just follow up a bit on that. Does the Air Force use polyex in its airplanes?

WITNESS SLENSKI: I am not aware of polyex being used in any Air Force aircraft. I think it has been used on some military aircraft, but I am not aware of it on Air Force aircraft in general.

DR. LOEB: But, you do have Boeing -- Boeing Aircraft --

WITNESS SLENSKI: That's true, so I guess it is possible, then.

DR. LOEB: But, in general you are not aware -- in general, what kind of wiring is used?

WITNESS SLENSKI: Well, there are several types in there. As we have seen, teflon is one of the insulations . One of the insulations is 81-381, or polyamide insulation. That is also known as a trade name by Kapton, as an example. That is used extensively on aircraft.

Mr. Taylor mentioned the cross link tepsel. That is an insulation. We have some newer insulations out there today we refer to as hybrids, and that is a combination of a teflon with a polyamide insulation, and there are some older insulations out there, too.

So, there is quite a family of insulations out there. All of these insulations meet aerospace requirements . Obviously, there is -- over the years we have learned some deficiencies in these materials, and when we do that, we do take some action to minimize those types of problems.

DR. LOEB: Have you run into problems with arc tracking in any of your wiring?

WITNESS SLENSKI: There have been arc tracking events. I think any insulation can suffer what we call an arc track event. Mr. Taylor, I think, referred to this, too. All our insulations we are using today are very thin wall insulations for weight savings, as we recognize there is quite a bit of wire on an airplane.

150 miles of wire, if we can reduce the thickness of that insulation, especially when you are in the twenty gage range, the insulation is a contributor to the weight and volume of the insulation. It is significant.

so, we have designed down the size and volume and weight to save for aircraft design purposes. But, these insulations, because of that -- I think we have taken that into account.

Also, I would like to follow up what Mr. Taylor had mentioned; you know, for anti-chaffing the best solution is in your initial design, and we go to great lengths. I mean, we have government committees, which I am on, and also industry. There is the Society of Aerospace Engineers.

We had talked about installation, and we do have rules that we have and guidance on how do you install wiring. As Mr. Crow mentioned here, too, there is issues with maintenance induced chaffing, and that is something we are aware of, also.

DR. LOEB: Let's get back to arc tracking for just one minute. Is that a kind of an aging problem?

WITNESS SLENSKI: Well, I can show you an example of an arc tracking even because it is in my presentation. So, maybe we can get --

DR. LOEB: In fact, maybe we want to let you finish your presentation.

WITNESS SLENSKI: I am going to get to that in just a moment. If we go to the next chart.

(Next slide shown.)

I think I am going to skip -- let's see what the next chart is you have here for us.

(Next chart shown.)

Okay, this was an actual example of aging, but this is a little bit different situation. This is where the conductor is causing us a problem where we have a -- if we go up to the upper left corner (indicating), and, again, we mentioned wiring the system and we concentrated quite heavily on the insulation. You also have to worry about the connector and the conductor also as an issue.

In this case, what we are looking at here is the resistance increase in the crimp joint, and if you could point – there is one of those crimps that is somewhat removed down in there. If you could point to that? Right there (indicating) .

That actually caught fire, and what was happening here is there was over a hundred amps of current going through that connection, and we had resistance drop across there. If you think about a resistor, if you have current going through that resistor you create heat.

We try to keep these connections at very low resistance. As that resistance increases, the heat is dissipated through the connection. In this case, it actually caught fire because it got so hot, and this was an actual failure mechanism related to the plating on the wiring over very many years of use and high temperatures. It actually degraded and eventually caught fire. So, this is just another aging issue you can deal with with wiring.

DR. LOEB: What kind of wiring was it?

WITNESS SLENSKI: This actually was teflon based insulation with a mineral fill material in it. So, the wiring insulation itself was not so much the contributor here, it was the actual interconnection that caused the failure.

You know, again, this is an example of failure analysis and that -- fortunately, in this case, this was just an incident in the aircraft. There was no loss of the aircraft, and Mr. Taylor mentioned it is always nice to get these exhibits back to a lab.

In this case, our maintenance was concerned about it. They removed that cable in there and got it back to our lab so we could understand what happened, and then we were able to take corrective action. That is, again, important to –– when you have failures, to identify the cause and then get some type of process in there to take corrective action.

If we could just go to the next slide, because I think this is -- the next one might be interesting.

(Next slide shown.)

Let’s go to the upper left first (indicating). This is an example of a -- this is a mishap of one of our aircraft. Fortunately, we had a fire in the rear of the aircraft and it actually developed while the aircraft was in landing configuration.

The airplane was able to get on the ground so that it was - although there was damage to the structure of the aircraft, the aircraft landed without -- safely. So, what we are looking at is the fire damage, and if we could go to the lower image in the center there (indicating), that is the hole that was left from the fire, and we have actually burnt -- melted aluminum, as you can see.

Now if we go up to the upper right (indicating), this is inside there, and what we are looking at is remains of the wiring, and I think you can possibly point to some of those. It is a little above that arrow (indicating) .

There was an extensive fire in here, and basically what happened is the wiring had chaffed against an aluminum hydraulic line. The hydraulic fluid is high pressure, so we had misting in there, and with the arcing there was ignition in there, and that is what caused this event.

To show that, if we could go to the next chart we will actually look at the hydraulic line.

(Next slide shown.)

The hydraulic line is in the upper left

corner (indicating) . What is interesting is that this incident –– and this is what we get into in, I think, mishap investigations –– if this incident had occurred at high altitude and the aircraft had actually impacted the ground, the possibility of recovering this type of hardware would have been very difficult to come back and find this type of evidence because, as I think I have mentioned, especially in electrical systems, they typically are damaged during post-mishap fires.

Typically they are low temperature materials, or organic materials. They don't survive well in the accident. So, it is very difficult to reconstruct what actually occurred when you are dealing with electrical systems.

If we go to the center -- lower (indicating) . That is the actual pitting that occurred in the aluminum hydraulic line where we had spewing of the fluid, and that is the actual erosion that occurred, probably over time in the aircraft. It eventually eroded through the wall of that tube.

Now if we go up to the upper right (indicating) . After this event occurred -- and, again, we understood what had happened. We go out and look at other aircraft, and this is that same hydraulic line, and we can see wires actually up against that line.

This was the chaff problem we were dealing with here. So, the solution here was to re-route those wires. So, we were dealing with a maintenance issue here that caused this failure.

MR. SWAIM: I would just like to note that the NTSB right now is investigating, or putting together a report on hydraulic line and wire chaffing. I believe that the original or the crux that led to that was in a Citation Jet, a corporate jet, and I was just digging through a pile of paper. We have gotten an lot of correspondence from people in the public.

This one is from a Mr. Jereky (sic) in Monroeville . It is exactly the same thing, electrical wiring, chaffing on a hydraulic line leading to a landing gear bay fire which we talked about yesterday. This one was in 1940-something. So, it is not a new problem.

WITNESS SLENSKI: As an example, well, what have we done to eliminate the problem? We went back to the lab and we have done some arc erosion tests on hydraulic lines to see if aluminum -- typically we use stainless steel lines. We don’t use aluminum anymore. This was an old aircraft type.

But, we have done some tests of how long can you arc before you actually expose the wall of the hydraulic line, and that is some of the research we have been trying to disseminate to industry.

WITNESS TAYLOR: Mr. Chairman, I would like to add something. We have one hundred forty-seven 747 wires which have airplanes which are wired with the polyex wire. We have no record of any incident of arc tracking taking place on any of the wires on any of these airplanes.

I just wanted to make sure that that goes into the record since we have been talking about arc tracking, that we have not any evidence on any 747 airplane of arc tracking of polyex wire.

CHAIRMAN HALL: Mr. Craycraft?

WITNESS CRAYCRAFT: May I add to that that TWA has had no experience whatsoever of arc tracking of this wire on a 747.

CHAIRMAN HALL: Okay, thank you.

WITNESS SLENSKI: In follow up to that previous incident I had shown you, these are rare events. They obviously are not occurring everyday. The same with the Air Force; we do have arc track events that have occurred over the years. It is not -- again, we don’t have polyex, and it is going to be the next slide that we will talk about arc track event.

(Next slide shown.)

This is an example, if we go to the lower left of a wire bundle. This is a polyamide insulation. Again, also identify the trade name Kapton. This is an example of an arc track event that came out of an aircraft basically initiated by a chaffing event.

If we go up to the center where we will get a close up of the damage (indicating) , and now I think if we go up to the upper -- where we actually see what is happening here, and this insulation, polyamide, is unique, and it is a tape-wrapped insulation. It is not estreated on the wire as we were seeing previously in the teflon. It is actually wrapped on the insulation.

It is unique in that the material does not have a melting point. At high temperatures it carbonizes . That is the evidence -- that is the issue here with arc tracking.

This particular material, if you do develop and arcing event - and of course you have to somehow violate the insulation and expose the conductor -- you can carbonize that area which is conductive enough to sustain arcing, and you can get what we call the arc track event.

It is rare. It has occurred on some aircraft. I personally am not aware of us losing an aircraft due to an arc track event. It has happened.

DR. LOEB: Have you encountered arc tracking on any wiring other than Kapton?

WITNESS SLENSKI: I am going to show you an example of one in just a moment of another insulation type. Any insulation -- and many of us in the industry have been running tests on Kapton insulation. Mr. Taylor has run quite a few on 81-381, or polyamide insulations .

All insulations in certain configurations can be forced to arc track, basically. If YOU put conductive solutions on there, vary voltages, you can get these events to occur. Any -- these are all polymeric materials, and they do have carbon in the chain of the materials, which is conductive if you can get it to form on the surface, or if you have another fluid that is carbonaceous we can actually initiate these types of events.

What we are really looking at here is arcing over time, and it is thermal damage through the arcing process. It damages adjacent wires which can propagate, and we do have circuit breakers that eventually will stop these reactions, but they encourage such a quick event that circuit breakers sometimes will not react fast enough to these processes.

If we go to the next slide.

(Next slide shown.)

I know there was some interest in hot stamp marking. This is a field failure of hot stamp marking and wiring that is on polyalkine insulation. It is a very -- it is an older insulation.

In this case here, your hot stamp process penetrated the insulation, conductive fluids were near this area and this was 115 volt three-phase power and we had arcing between the various wires in different phases, and that led to this failure.

I think if we go to the lower quadrant, that is an actual area where it was hot stamped at one time. Again, as I mentioned I believe yesterday, hot stamping is an acceptable process for wiring when it is controlled. You just have to be somewhat careful in that marking process. This is an example. This we call wet arc tracking because there was a fluid involved and, so, this was not dry arc tracking.

Then, the final slide.

(Next slide shown.)

I think this was discussed previously. This is a program -- again, if we go up to the lower left -- or, upper left (indicating) . We have talked about are there any ways to predict the life of our wiring, or evaluate its integrity, and this is just an example of wiring in an aircraft.

We have looked at some non-destructive techniques that can allow us to possibly find defects in wiring, and if we now move over to the upper right (indicating) this is an infrared technology here we are using.

This technique under certain conditions can actually detect breaks in insulations, or flaws in the insulation. We have a program now trying to determine if this can be used to inspect wiring and, again, this would be helpful in finding chaff damage or mechanical damage to the wire.

SO, there are other programs. Some of these are just some examples of how you can do this. There are other programs out there that are actually removing wire from aircraft and running some tests to predict the age of the wiring. So, there are actually several programs out there trying to develop a program for evaluating the aging or the integrity of the wire.

The last slide is just a summary here.

(Next slide shown.)

I really did not prepare to get into other components other than wiring. The general statement here when it comes to electronics -- and we discussed this a little bit -- but, what my experience has been is that it is the electronic systems that are what I call electromechanical in nature that we seem to have the most problems with aging. That is the wiring, the connectors, solder joint switches.

Anything that moves over time can experience some type of degradation. So, these are the areas that we have been concentrating on when it comes to aging of electronics .

DR. LOEB: Is the intention to develop a program specific to aging wiring?

WITNESS SLENSKI: There is an attempt, and I was giving you an example of trying to assess the wiring age issues. We are looking at the possibility of that. Again, it is more of a broad umbrella when we are talking about aging of electronics and structures where we are looking at all these types of components.

I think what I tried to do at the next bullet there was try and give you -- this is my opinion about if we are going to look at these issues what we have to do.

First of all, you have to verify your failure, and that is usually through –– what I usually do is physics of failure actually determine cause of failure. Relate that to design, materials and manufacturing process, come up with your corrective action and decide if –– make sure everyone in the industry knows about the problem, and if you need to do more research in the area to initiate research initiatives through a cooperative effort.

As we have reduced budgets, we all have to work together. So, we try to now initiate cooperative efforts if we find deficiencies.

MR. SWAIM: Thank you, Mr. Slenski. I think that would go back to Mr. Dunn, because you are talking about programs and industry and so forth. My -- how would that tie in with you? Are you bringing that into your program?

WITNESS DUNN: Well, can you be more specific on what things you are talking about?

MR. SWAIM: As far as looking for wiring problems, active hunts for wiring problems rather than on condition type maintenance?

WITNESS DUNN: Yes, most certainly the plan that I talked about earlier does intend to look into issues of wiring, specifically. Also, George mentioned tools, tools for finding out if we have defects in wiring. That is also an issue we will be looking at as we do our field inspections.

We are going to look at DC-9's, DC-10'S, Air

Bus 300, DC-737's and we will be looking at those issues specifically, yes.

MR. SWAIM: Okay. I would like to, since --

CHAIRMAN HALL: Who is the FAA wire expert? Is that Mr. Crow, or do you have a wiring expert equivalent to Mr. Slenski or Mr. Taylor?

WITNESS CROW: Mr. Chairman, I don't know in particular anyone that is the wiring expert in the FAA Flight Standards. That would probably fall back to the Certification Service somewhere. So, I --

CHAIRMAN HALL: It is probably Mr. Dormer. Let's go ahead.

MR. SWAIM: Okay. My question for Dr. Dunn, then, is, using as an example the 1991 recommendations from the Safety Board following an L-1011 incident, an in flight fire from wiring, we are recommending –– the Board recommended, I am sorry -- that the FAA notify all the operators of lint build–ups and foreign materials in the wiring and clean the wiring, and I am using that as an example.

How do we know that your programs that you are talking about are going to take effect, because we were examining airplanes that if they had been taken out of service earlier this year would have been examining operational airplanes and we are still seeing lint and other debris in the wiring.

WITNESS DUNN: I guess when you say "how do we know the programs are going to take effect, " what -- can you be more precise?

MR. SWAIM: Well, you have spoken several times about issuing a recommendation sometime around June.

CHAIRMAN HALL: Well, he has discussed this several times, Mr. Swaim. He is developing a program, and I don't think you have the program right now, right, Dr. Dunn?

WITNESS DUNN: No, sir, I don't.

CHAIRMAN HALL: And they will have the program in June of next year.

MR. SWAIM: Okay, well, we will wait and see.

WITNESS DUNN: Mr. Chairman?

CHAIRMAN HALL: Yes.

WITNESS DUNN: At some time I think it would be useful for the American public to get kind of a better overview to the industry's approach to aging systems as it exists now. We kind of talked about it a little bit. We have talked with Mr. Craycraft, we talked a little bit about Boeing, but I think it would benefit the public and the record, certainly, if we spent maybe – and digressed about ten minutes.

I have some comments I would like to make, and I think Mr. Crow would also like to, I think, step back a little bit. We have talked about a lot of very specific things of wire. At some point during this panel discussion, whenever you think appropriate, I would certainly like to --

CHAIRMAN HALL: Well, this would be fine right now, Dr. Dunn. Please proceed.

WITNESS DUNN: Okay, fine. I think my -- I do want to say that -- I have a few comments, and then I would like to pass it over to Mr. Craycraft to further comment on the maintenance aspects.

With that said, I think it is important to talk a little bit about our current approach to aging systems and how we address aging systems now, because I feel it is a good story, I feel that we are doing in general a good job, but I want to preface my following remarks with saying that there is always room for improvement, and we continually are looking at the system.

CHAIRMAN HALL: Well, and let me just inject, Dr. Dunn, so that, again, the American people know that the Boeing 747 has an outstanding safety record, and I think that is part of our public information and is part of the docket that has been submitted.

Obviously, the whole aviation safety record in the United States, if we would have the same safety record on the highways we would probably save in excess of 35,000 lives a year.

So, but what we are doing here and what the Board is tasked is the responsibility of through this accident investigation and working with the FAA and the parties trying to explore every avenue, because we don't know. If we knew, it might be a different situation, but we don't know, so we are trying to look and be sure that the American people know that we have looked at each and every possibility so that if there is --

We can do two things. One, hopefully find the probable cause of the TWA 800 tragedy and, secondly, advance aviation safety through the public dollars that are being spent on this investigation, which is certainly not a small sum of money. Please proceed.

WITNESS DUNN: Thank you.

(Tape change.)

First of all, on the design side of the house, the Aircraft Certification Office, there is a lot of ways that they get involved in the continuing process.

Maintenance and the operator handle the aircraft once it has been approved in design. However, the engineering gets involved still to a great extent. We have all talked about Airworthiness Directives today which are areas where -- where we find an unsafe condition and then we correct it. That is certainly one area that the Certification Engineers get involved.

In addition, there are daily reports which come to the engineers and to the maintenance people in the Certification Offices which are reviewed so that people see on an ongoing basis what problems are out there with the operators, the air traffic controllers, what kinds of things they are saying.

SO, this gives us additional opportunity to look at the ongoing way the airplane is being operated in service and the way it is being maintained and it is operated to make sure it continues to be safe.

As well, when we go and we approve the design, we have safety analysis. We have talked about that a little bit previously. But, I do want to say that when you talk about aging you are talking about deteriorating effects. You are saying the wire chaffed, the wire shorted and things like that.

Well, when we design the airplane we postulate right up in the beginning that these things are going to happen. So, when the safety analysis is done, and we do this as part of the design and approval process, we postulate these shorts, we postulate the fact that these kinds of events will happen. Even though we aren't thinking in terms of aging, it actually is aging related.

so, those are some of the areas that we get involved in, but after that, of course, there is a whole maintenance program that is set up with the operators that is done under Part 121 for large transport aircraft. That is where Bill Crow I think could perhaps give you some comments.

WITNESS CROW: I would be happy to share that information with you, Mr. Chairman. I think it is important because it does, as I indicated earlier, close the loop, if you will, on continuous airworthiness concerns and the programs and policies and procedures that are in place.

I am not going to endeavor to quote any Federal Aviation Regulations, or even paraphrase them, but for the record I would like to give just a few -- four that are appropriate that all of the air carriers use in the performance of their maintenance and such as that.

Of course, going all the way back to Part 25, this is a very important thing. It is the design criteria for certification. But, in particular, one that we are very interested in today is 25-571, the damage tolerance and fatigue evaluation for transport category aircraft.

As Dr. Dunn spoke earlier, the Appendix H of that does require specifically that continued airworthiness maintenance manuals and limitations be provided to the operators of those aircraft for the continuous maintenance of that particular airplane.

In addition to that, we have to go back into the FAR and we look at 4313 A and B which are performance rules that are mandated to all people at all categories of airplanes for the safe and efficient maintenance of those aircraft.

Then we go to 4315. 4315 is additional performance requirements that are placed on the industry for the maintenance of their aircraft. We go to 4316 which basically has to do with operation specifications, and the key element in that FAR is a statement by the Administrator that says that the agreements that are reached in the authorization document, the operation specifications between the air carrier and between the FAA are mandatory and must be followed, and that takes us to the aircraft maintenance manuals and the continuous airworthiness maintenance program.

We also have 91-409, that in paragraph E and F determines the types of requirements that are put on the major carriers. In this particular case, all FAR 121 aircraft, and even those in the 135 category, as we know, they are now falling under 121 rules for continuous airworthiness maintenance programs.

We have a 119-43 which again talks about -- this is one of our new FAR’s that talks about operation specifications and reiterates the responsibility to follow those.

121-367 is the first 120 regulation -- 121 regulation that we talk about, and it identifies the maintenance programs that must be in place by regulation for maintenance -- preventative maintenance and alteration. Then we go to one very important consideration within that 121 reg. It is 121-373, continuous analysis and surveillance.

In all of these programs are the things that our friends down there at the IAM table deal with on a daily basis. These are the people that are responsible for the continued airworthiness of the airplanes that are flying out in industry.

These are the people that are working in coordination with our engineer friends in the Aircraft Certification Service and with the FAA, in particular Flight Standards Service. The work that they do has an immense impact on the way the aircraft perform the longevity in service and airworthiness of those airplanes.

So, I would suggest to the Board that the continuous airworthiness requirements for aircraft really come in about three phrases, two that you can really lay your hands on in good fashion. One of them is the certification responsibility. In particular, 25-571. Then, the regulations that I have given you are those maintainability and performance regulations.

The importance of this thing from a Flight Standards perspective is to understand that we are immensely interested in the level of safety, the inherent level of safety that is designed into the airplanes and the level of safety that is placed in the airplanes on a daily basis by the mechanics.

We can spend an eternity looking at certification issues, and if we ignore the maintainability side of the airplane, then we have done half a job. That is a Bill Crow opinion, that is not the Director of Flight Standards opinion, and I want to go on the record as saying that.

It is very important to understand that within those maintenance programs that our friends from TWA and the major carriers and all of the carriers certificated under Part 121 for that fact, the programs that they have offered great evidence as to the systems function, Dr. Loeb.

One of the things that you find when you look at aircraft specifically as an entity, as an electromechanical machine, is that there are certain criteria, there are certain things in that airplane that are critical zones, critical environments.

In listening to the testimony today, I couldn't help but sit back there in the observer's area and recall the many times that I have been in fuel tanks and knowing what that critical environment is.

Another critical environment is the aircraft wiring, and the point that I would like to make regarding that, calling those critical environments is -- 1 would like to give you an analogy, if I could. The analogy would be one that runs to someone that is a surgeon, if you will, and is going to perform surgery on a gurney or an operating table in a hospital.

If a person was to go in for major surgery at some time and he had a specific symptom, then that surgeon would go in there and he would do -- he and his team would go in and do the work that needed to be done, and while they were in that general area, as we refer to on air carrier maintenance, in particular MSG-2 and 3 aircraft, the zonal concept of inspection, he would look around in there and see what else he could find, and we would do the same thing on the zone concept of the inspections that we use for the aircraft on the continuing maintenance requirements when an airplane is in service.

But, I don't believe that a surgeon would go in without symptomatic cause, or purpose, or intent and perform surgery in an area that was critical to the well-being of that patient.

For the same purposes, our mechanics that are represented by the IAM and other people that are maintaining these airplanes, we like to go into these areas that are considered to be critical areas, critical environments, on a need basis.

If we open those areas, if we open those fuel tanks, if we get into systems maintenance where there is no symptomatic indication of a problem, sometimes, as was brought out in the expert testimony before, you can cause more damage than you may have during the life cycle of that particular airplane. So, it is very -- it is a very -- it is a very passionate discussion when you get into trying to determine the right thing to do.

The Federal Aviation Administration, and I am speaking on behalf of myself and, again, not for the Director of Flight Service -- Flight Standard Service, but it is very important that we stand firmly in our position as given to us in the regulations.

We should not blow with the wind in one direction, or blow with the wind in the other direction. We should not take action until such time we are absolutely sure of the probable cause, because when you develop a periphery of perception, you may do exactly the wrong thing.

I wanted to share these with you because I think it is important when we look at this TWA 800 accident and the people that have lost loved ones and all of the things that circle -- that come around this, we in Flight Standards right now, we really have no probable cause, as you have no probable cause.

We have ideas, but it is very difficult to stand firmly in that position and not waiver until such time we do have the findings we can really work with, and I think it is important to note that when the Flight Standards does have that information, they will take swift and immediate action to make sure that that is remedied.

I think that the maintainability is a very important issue regarding this continue airworthiness thing, and moving away from certification to make sure that we recognize that.

One of the things that I recall listening to this morning is the discussion about structures and systems. I want to use some of my own vernaculars to try to describe this, and my engineering friends here may disagree with what I say, but I think they will know where I am coming from.

When you start looking at aging aircraft and you start looking at the symptomatic problems, that you see there are a lot of latent failures that you don't see. That is inherent in the way we look at some of the airplanes. For instance, the structures, the primary structures of an airplane probably fall somewhere between passive and dynamic, where the systems on the airplane are typically dynamic.

As George Slenski indicated earlier, most symptoms that are identified in systems problems are systems that have rotating parts that are driven by electromotive force. They have some sort of a mechanical function, where the structures don't. As I indicated, they are from passive to dynamic, so we don't see those.

But, when you have a failure in a system, even with associated wiring you generally have some sort of a symptom. You generally have something like that. So, the air carrier industry has the reliability programs where they take the pilot reports -- and we refer to them as pi–reps. Our friends at the Air Line Pilot's Association know well what those are. They drive the air carrier reliability programs.

They set alert levels for the maintainers, such as Mr. Craycraft and others in the engineering functions to look at to see how those systems are performing. It is not as if as we speak there is not programs in place that are not necessarily required by the FAR, but that are encouraged by the FAA to identify systemic problems that will show degradation of the systems.

In addition to that, the one FAR that I suggested to you, the FAR 121–373, is the continued analysis of surveillance requirement, and it is mandatory. This is a continuing certification requirement for an air carrier certificated under Part 121.

To fail to meet that requirement would place a certificate holder's certificate in jeopardy. This is the item that causes the certificate holder to determine through careful analysis the performance of their maintenance, preventative maintenance and alteration.

It also causes them to look and analyze all of the activities surrounding the maintenance organization. The basic difference between a CAS program that is mandated by the FAR and the reliability program, as far as being able to make determinations on the reliability of the aircraft or the systems, is based in one thing; with the reliability program the operator has the authority without prior approval to adjust maintenance and inspection intervals, where with the CAS program they still come to the FAA before they make those changes.

SO, there are a lot of devices, there are a lot of processes and a lot of programs in place that support continued airworthiness of these airplanes that are designed by our engineers and built by our manufacturers, purchased by our air carriers, flown by our pilots and maintained by the maintainers.

SO, I want the general public to know that once an airplane leaves the drawing board and once an airplane leaves the manufacturer, once that airplane is in service that airplane is maintained on a daily basis in strict accordance to the regulations.

But, for the most part -- and that is probably a bad choice of words, but I don't know what other vernacular to use, they are being maintained at a very high state of airworthiness.

The anomalous situations that do occur with the tragic catastrophic problem that occurred with TWA 800 and other aircraft probably are a small place on an array of data. But, nevertheless, there are no unacceptable losses. We can't have –– there are no acceptable losses.

But, the continued airworthiness maintenance program that is provided under the regulations and overseen by Flight Standards Service in conjunction with and coordination with where problems arise and things are identified that need to be fixed with the Certification Service, they are being looked at on a continuous basis.

We spend a great deal of time with our certificate holders and we are very cognizant of the need for change, and we would just like to make sure that the Board is very aware of its continuous airworthiness requirements, aside from the certification issues.

CHAIRMAN HALL: Well, thank you, Mr. Crow, for that presentation. One clarification I want to be sure of, though, so there is no misunderstanding, I think, with the general public. If the FAA and the NTSB find problems with any particular aviation accident investigation, I don't think you were saying that the FAA is going to wait until there is a probable cause to act on those problems?

WITNESS CROW: No, sir, you are exactly right. We would not wait and we would cooperate very professionally and effectively with all of the other entities that were working. But, one of the most difficult things to do in this world is to identify a corrective action for a discovery that has yet to be discovered.

SO, we want to go on record and we want to continue to say that we are very interested in knowing anything and everything about the accident where we may take appropriate action.

CHAIRMAN HALL: Okay, other comments? Do yOU want to continue on?

(No response.)

What I am going to suggest doing is continuing until 12:30, and take a one hour lunch break to 1:30. Again, I know the only people that are interested in this going to day five are probably the taxpayers of Baltimore, but nevertheless we need to finish our work here and I would -- the prudent --

Everyone is asking me for advice, and the prudent thing I would suggest is be prepared to be here tomorrow. If we can finish today, fine, but if in terms of -- I know people have hotel rooms and flight reservations, and I would say that the prudent thing to do is to plan for departure tomorrow.

We have not gotten into the AD Service Bulletins on TWA 800, which is something I would like to do before we get to do the parties. But, possibly, Mr. Swaim, unless you have something else you want to get into, we will just take a little longer than usual lunch break, and we will reconvene here promptly at 1:30. Off the record.

(whereupon, at 12:15 p.m. a luncheon recess was taken.)

A F T E R N O O N SE S S I ON

(Time noted: 1:30 p.m.)

CHAIRMAN HALL: We will reconvene this public hearing of the National Transportation Safety Board that is being held in connection with the investigation of the aircraft accident involving Trans World Airlines Flight 800 that occurred eight miles south of East Moriches, New York on July 17th, 1996.

Let me state, again, for those who are observing that they can follow –– get information on this hearing at the NTSB web site, NTSB -- I mean, www.ntsb. gov.

Let me again say, as I said in my opening statement, that public hearings such as this are exercises in accountability, accountability on the part of the National Transportation Safety Board that it is conducting a thorough and fair investigation, accountability on the part of the Federal Aviation Administration that it is adequately regulating the industry, accountability on the part of the airline that it is operating safely, accountability on the part of manufacturers as to the design and performance of their products and accountability on the part of the work force, pilots and machinists, that they are performing up to the standards of professionalism required of them.

While these four days of proceedings have been highly technical affairs, I again would like to state that I think that they are essential in seeking to reinsure the public that everything is being done that can be done to insure the safety of the airline industry and find the probable cause of the TWA 800 tragedy.

Mr. Swaim, please proceed.

MR. SWAIM: Thank you, sir. I only have a couple more, and we will be into Debbie Eckrote and Maintenance Records, the maintenance of the airplane.

(Slide shown.)

The photo -- there are two photos there, one in the upper left corner and one, the larger photo. The smaller inset is of a wiring fire, and the other is of lint on wires we found behind a flight engineer's panel of another 747.

My question is to Mr. Taylor, Alex Taylor. In your reviewing wiring problems and aging wiring problems, does it taken into consideration problems that can happen in a general area like this, or is it more to an individual wire?

WITNESS TAYLOR: I don't really understand the question. Could you re-word it a little bit, please?

MR. SWAIM: In the consideration of aging systems, and you spoke very well about wiring, was that mostly pertaining to individual wires, or bundles of wires? That is where I came with this question from.

You spoke of bundles of wires, but in this photo we have a number of wires -- bundles shown together. Would that type of review be on a detailed engineering paper level where it would consider just a bundle, or would it consider an area such as seen here with a number of bundles?

WITNESS TAYLOR: When I refer to wiring on an airplane, I refer to all the wires on the airplane in whichever particular configuration that may be at whatever location on the airplane. Wiring is wiring, whether it is a single wire, or a bundle, or a bundle of bundles.

MR. SWAIM: SO, for the failure considerations from aging, would it include a failure of a bundle -- I am not making this clear, I guess. Would it include -- is there some type of detailed or systemic analysis to include all the bundles within an area as you see here?

WITNESS TAYLOR: In the analysis that is undertaken, the design of the bundle is such that we can lose a wire within that bundle and it will not affect the safety of the airplane, or we can lose a few wires within that bundle and it does not affect the safety of the airplane. We can lose that whole bundle and it will not affect the safety of the airplane.

MR. SWAIM: Lose that whole area with the lint build-up on it?

WITNESS TAYLOR: That is an area, that is not a bundle. That particular photograph you have there is more than one bundle. It is an area, but within that area there are numerous bundles, and many of them are separated from that picture by a foot or more, and that is more than adequate separation to make sure there would be no propagation of any failure of one of these wire bundles to another.

MR. SWAIM: Okay. I would like to move out of wiring, we have been discussing wiring very extensively, and ask a couple of questions of Mr. Thomas about leakage.

When we discuss leakage, this is a photo we have seen before of the corner of a corner in the center tank, and there are three colors that can be seen of sealant, and when we discuss fuel leaks -- and we are showing different layers of sealant here -- when we discuss fuel leaks in aging aircraft, how is that considered, Mr. Thomas?

WITNESS THOMAS: Fuel leaks are considered right from the start of the design of the airplane. We recognize that at some point the wings are flexing. Most all our fuel tanks are generally located in the wing. The wing flexes up and down. Occasionally we will develop leaks.

That is taken into consideration right from the beginning of the design of the airplane. We assume that we are going to have fuel leaks. We typically will -- typically all the time we will divide the airplane into zones. The leading and trailing engines, for example, are considered fuel leak areas where a single failure can cause fuel to leak into those areas.

We require all the electrical components in the leading and trailing edge to be explosion proof. We require that temperatures of ducts to be below 450 degrees Fahrenheit, again, for hot surface ignition issues.

We provide very careful drainage and dams in the leading and trailing edges to assume that any leak is directed to a drain hole and overboard safely. For instance, if you have a leak outboard of a strut, we will have a dam outboard of the strut to stop the fuel from running down onto themselves where it may catch fire in the engine area.

The same thing at the side of body. There is a seal rivet the side of body. So, again, if I have a leak inboard of the engine, it will just run to the side of body and go overboard through a drain line and not propagate anywhere that it could be hazardous.

Does that answer your question?

MR. SWAIM: Would the area under the tank, below the center tank in this case, be considered an area that you have to run the same electrical protections as you would in the fuel tank for ignition?

If you have a leak out of the fuel tank into that area below the fuel tank, and you have wiring down there, what consideration is given for the fuel -- which one is the latent failure, or trying to prevent a latent failure, that you could have the fuel, say, leak onto a bundle of wiring, or if you have wiring that ignites a fuel leak down in that area?

WITNESS THOMAS: Out there you are dealing with the first failure which is a leak, which is readily available – readily observable to the crew or to mechanics doing a walk around the airplane. You will see the fuel dripping out of the –– in this particular example you have chosen, the pack bay area.

The pack bay is designed to be -- all the temperatures in the pack bay are below 450. By design the hot air that comes from the engines are controlled to below 450, as I have discussed several times in the last few days.

The packs themselves, although we talk about them being hot, are all running in the -- at the maximum, something in the 350 range, and a lot of the packs are much cooler than that.

None of those are ignition sources. The electrical bundles, as far as I know -- and I would defer to Mr. Taylor on the details of connectors -- are not a source of ignition while that leak is taking place.

The assumption that we would make is that the leak is very detectable and the airlines can fix the leak. We have very carefully defined -- and I can't quote them off the top of my head, but we have very careful ways of defining a fuel leak, whether it is a weep, or a seep, or whether it is a drip and what procedures go along with repairing the airplane when those things take place.

MR. SWAIM: Okay. I think at this point I would like to turn it over to Ms. Debra Eckrote. She is our Maintenance Group Chairman for this accident.

MS. ECKROTE: Thank you, Bob. I just have a couple questions. The first one I would like to ask of Dr. Dunn. Earlier we had been talking about the corrosion control program and the structural inspection programs.

Would you please discuss the AD's and Service Bulletins that have been generated as a result of these programs, and also would you also discuss if there are any future AD's or Service Bulletins that are being proposed?

For reference for the audience, the list of all the applicable AD's on the aircraft at the time of the accident can be found in Exhibit 11-P. Mr. Dunn -- or, Dr. Dunn?

WITNESS DUNN: I can't address corrosion AD's. That is not an area of my expertise. However, I do have some overheads that we can show that talk about AD's that we have put together since we have known about this accident.

MS. ECKROTE: Thank you.

WITNESS DUNN: This is the first one we will talk about.

(Slide shown.)

Incidently, I want to make clear that I am presenting these slides on behalf of Chris Hartonis (sic) of the Seattle Aircraft Certification Office who did prepare these for me.

This first AD that I am going to talk about here is actually an NPRM. It says “Air Worthiness Directive,” but it is actually at this point an NPRM that is out for comment.

It was published in the Federal Register I believe the first of this month with a ninety day comment period and a one year compliance. This involves 747 fuel quantity system wiring. That is an AD that relates to the wiring on board the aircraft in order to prevent ignition sources from entering the fuel tank.

Next slide, please.

(Next slide shown.)

What this AD proposes to do is to install transient suppression and/or shielding and separation to the wiring of the FQIS system.

Next slide.

(Next slide shown.)

I guess it is appropriate at this point to discuss what shielding is and why it is important. As it says up there, shielding is electromagnetic. Electromagnetic shielding is a technique that reduces or prevents coupling of undesired radiated electromagnetic energy in equipment.

The concern here is obviously coupling energy from one wire into another wire such that you would ultimately get a certain amount of energy, if you will, into a wire which might subsequently –– that energy might find its way into the fuel tank.

Next.

(Next slide shown.)

A transient suppression device is a device used to limit the amount of energy. It is a surge protector, so that if you get this coupling from one wire into another, this energy coupling from one source into another, you want to make sure that if indeed it does happen you can make sure that that energy is not propagated ultimately into the tank.

SO, what you do is you insist that you stop that from happening, or essentially cause that energy to be shorted to ground prior to entering the fuel tank. Shielding is one way of doing this. Using a transient suppression device is another way.

Next.

(Next slide shown.)

So now what we have got here -- as this AD relates to this accident, what we have got here is we want to make sure that we don’t get any kind of energy into the fuel tank from whatever source, and we –– and, So, what we have done is we have gotten very –– shown here is a bunch of sources here of possible energy sources that might get into the tank.

On the left you have voltage sources, induced transient, one wire, like someone shuts off a switch or something and that wire – the energy in that wire is a result of the –– of –– that transient is produced and couples into another wire. So, that is the first one there.

Then, of course, the hot short where you have a chaffing of that where the energy from one wire physically touches another wire and subsequently might -- that energy might get into the fuel tank.

On the right are sources within the tank of possible -- possible debris and possible conducting sources. You have copper sulphite, as we talked earlier, and you have debris, maybe wire shavings and things like that, damaged wire insulation and damaged probes . All of those are sources we need to protect against.

Next.

(Next slide shown.)

What this slide attempts to do is to show you kind of what really happens when you get induction, and it is for illustrative purposes only. At the top you have a motor in one system and then -- represented as a wire between an indicator and a motor, and then at the bottom you have yet another system. As a result of a common bundle they come in contact with each other.

So, what you are trying to do with this AD is to put in place methods whereby you can't -- you suppress any coupling from one wire into the other, and the three techniques that we have talked about were in separation where we can make those wires –– we can separate those wires.

We can shield one of those wires so that it can't –– the energy cannot couple into the other, and then we can –– also, a third technique would be to use a suppression device prior to the fuel tank to insure no energy enters the fuel tank.

Is there another slide, or is that it?

(No response.)

Is that it? Okay. So, that is the current NPRM that we have out now that we are trying to address. Now, there was also a question that related to other AD's, is that it?

MS. ECKROTE: Do you have any knowledge of the AD's that are presently open regarding the structural inspection, or the Corrosion Control Program? Can you discuss that? Or, I can direct that maybe to Mr. Craycraft and see if he can kind of discuss some of that during his maintenance review?

WITNESS DUNN: Yes, I -- I am not really --

MS. ECKROTE: Okay.

WITNESS DUNN: I can't really address that. I did want to –– I should reiterate that that is an NPRM that is out now for comment.

WITNESS VANNOY: Debra, this is Bob Vannoy. I can summarize those AD's for you, if you would like.

MS. ECKROTE: Thank you, please.

WITNESS VANNOY: Okay, out of the activities that were generated after 1988 with the Structures Task Groups there were three main areas that were covered by AD's.

Number one was the Mandatory Service Bulletin Modification and Inspection Program. The second was the Corrosion Prevention and Control Program. The third one was the SSID Program which previously had an AD, but new work was done.

In all three cases, the working groups, the airlines, Boeing and FAA, as observers and advisers, prepared documentation. Boeing put out the documents, and then the AD's that followed were fairly simple and just said go do what is in the document.

SO, for the Mandatory Bulletin Inspection and

Modification Program the AD was fairly simple. It was 90-06-06. Early in 1990 it just said go do what is in the Boeing document, which was a D–6 document produced by Boeing and contained a list of all the bulletins covered, and then the airline took that and had to pull out all the bulletins and then go put all that in their Inspection and Maintenance Program.

MS. ECKROTE: Are these AD’s a one time event, or are these repetitive?

WITNESS VANNOY: Well, for the Mandatory Modification Program, that is a one time event. When the airplane reaches the prescribed threshold you do the parts replacement, or whatever is called for.

The Corrosion Prevention and Control is ongoing. You have to establish a program for every airplane and do that work essentially forever. The SSID applies, as I said this morning, to the sample fleet, and that is ongoing as long as those airplanes remain in service.

MS. ECKROTE: Thank you. I think it would be a good time right now if we can ask Mr. Craycraft –– we have been hearing a lot of testimony about all these programs, but we haven’t really heard how TWA incorporates it into their program.

Mr. Craycraft, could you spend a little bit of time. I know this is a broad area and you could spend all day on it, but if you could just highlight your –– a break–down of your scheduled maintenance, and I know the Chairman had a question yesterday about the frequency of scheduled maintenance, and I don't think we really got a good answer on it.

Would you please also discuss the frequency that TWA inspects their program -- or, inspects their aircraft?

WITNESS CRAYCRAFT: Okay. If I might, I would start at the most frequently accomplished task, which is a periodic service. That is the identification that we put on it. That is accomplished at a maximum interval of every other operating day when we accomplish a periodic service.

The next level of maintenance is accomplished. We call it an aircraft service, or an AS. That is accomplished at intervals not to exceed 100 hours of aircraft time in service.

These are accomplished at numerical increments. There may be an AS-1 and an AS-2, an AS-3 and so forth until it gets up to the next level of maintenance which is a time control service. The time control service is accomplished each 1,200 hours of service and, of course, a TCS includes all of the items that are required on an aircraft service.

Then the next level of operation would be a Check-C. A Check-C is accomplished at intervals not to exceed thirteen months. We have gone at different times with an hour interval on our Check-C, but we have since changed to a monthly control to kind of fit in with the Corrosion Control Program. So, that is why we went to a monthly figure on the Check–C.

I think we referred to the Check-D, and I am looking here. I thought it was an op-16. No, here we go. op-16 is what is commonly referred to as a D-Check under some or other aspects.

An op-16 is a number of unit changes that we schedule, structural checks and inspections. That is the time that we get into the center wing tank for structural inspection and so forth. That is scheduled not to exceed forty–eight months for accomplishing an op-16.

MS. ECKROTE: Is the D-Check the heaviest maintenance activity?

WITNESS CRAYCRAFT: Well, we do have another check that is accomplished at every other D–Check that is called an Op–1, and it gets into further structural items also.

But, it also –– anytime we do any op–16, which is every forty–eight months, then all of the lower checks are accomplished during that time, and then when we –– if we were not doing an op–16, then we would do the Op–1 and it would include everything that is in the op–16.

MS. ECKROTE: Thank you. At the op-16, the D-Check, is it at this point that, say, like the floor boards are pulled up exposing wiring systems for inspections?

WITNESS CRAYCRAFT: Well, it does get opened up quite considerably, but the primary open-up activity is for gaining access to all of the areas for structural inspections.

While we are in there for the structural inspections, our dear friends our inspectors, they have what is called an area inspection and they are responsible for inspecting all of the items that is in an area, and if --

1 will use the center wing tank as an example. They are obliged to look at the fuel quantity equipment, the wiring, the plumbing and everything else that is in the center wing tank.

MS. ECKROTE: Are these area inspections pretty common throughout the aircraft, not just the center tank?

WITNESS CRAYCRAFT: That is correct. I just used that as an example.

MS. ECKROTE: Thank you. I think those are all the questions I have for this area. Unless someone has any questions, we can get into the minimum equipment list items.

CHAIRMAN HALL: Yes, I had a question I was going to ask Mr. Craycraft. I believe on the accident aircraft there were twenty–six fuel pump write–ups from July 1, ’94 to July 17, ’96. Is that an unusual number, or is that a standard number?

WITNESS CRAYCRAFT: I sounds a little unusual. I have not reviewed the fuel pump. I was looking at other items on the aircraft, sir.

CHAIRMAN HALL: Mr. Vannoy or Mr. Thomas, are you all familiar with the Service Bulletin 74728-A-2194 that was issued August 3rd, 1995, revised January 18th, '96?

WITNESS THOMAS: Is that the boost pump?

CHAIRMAN HALL: Yes.

WITNESS THOMAS: Could you give me the title of that if you have it in front of you, sir?

CHAIRMAN HALL: Yes, it is the Fuel Distribution Fuel Boost and Override Jettison Pumps Inspection.

MR. THOMAS: Oh, this is --
CHAIRMAN HALL: In the background it starts off, “This inspection will make sure the 747 fuel pumps will not cause a leak, a fuel leak,” and it says here, “Boeing recommends that the initial inspection be accomplished at the next opportunity.”
I believe this is the only Service Bulletin that was not -- that had not been accomplished on TWA 800, the accident aircraft. If I am incorrect in that, Mr. Craycraft or someone at the TWA table I am sure could correct me. but I would like to know exactly what –– a little background on that Service Bulletin and what ––
WITNESS CRAYCRAFT: If I might, sir?
CHAIRMAN HALL: Yes, sir.
WITNESS CRAYCRAFT: That Service Bulletin was being in the process of being evaluated and paperwork prepared to be accomplished on TWA aircraft, but at the time of the accident, then it became an AD and, so, it was accomplished shortly thereafter.
CHAIRMAN HALL: Okay. Could we have a little explanation from either Mr. Thomas or Mr. Vannoy as to what that Service Bulletin was all about, or is –– I don’t mean -- if you are not –– maybe there is going to be somebody else who could discuss that.

WITNESS THOMAS: My problem right now is there was –– is this the conduit AD, or is this the boost pump?

CHAIRMAN HALL: It says, “Since operators have sent reports of fuel leaks at the fuel boost and override jettison pumps, reports tell that eight fuel pumps have been removed for this reason. The removed fuel pumps had between 34,000 and 67,000 hours,” et cetera, et cetera.

WITNESS VANNOY: I think that is the connect --

CHAIRMAN HALL: It says that there should be an initial inspection at the next opportunity when manpower facilities are available, and then it gives some parameters on replacing the pumps.

WITNESS VANNOY: Yes, I can provide some background and current status on that bulletin. The bulletin was out before the accident, and you have a copy there.

The concern originated when we had a leak on an airplane that was in maintenance, and at the same time there was an electrical short in the connector and there was a small fire started in maintenance outside the fuel tank.

After that we initiated an Alert Service

Bulletin to do some checks on the connector for the possibility of leaking, and also an electrical check to check for the wiring condition.

After the accident, that bulletin was made an Airworthiness Directive, but the alert status of the bulletin was pre-existing and the FAA was in the process of doing that work before the accident, so it had nothing really to do with the accident.

CHAIRMAN HALL: Well, I am not saying that it did have anything to do with the accident. I just noticed that that was the only Service Bulletin that I noticed in reviewing the maintenance records, if I am correct, Ms. Eckrote, that Boeing had issued that was not –– the work had not been done on the airplane, and it had been put out initially on August 3rd of 1995. It said Boeing recommends that the initial inspection be accomplished at the next opportunity when manpower and facilities were available.

SO, I will ask Mr. Vannoy and Mr. Craycraft, is it a policy of most 121 operators that you all deal with, or –– and what is the policy of TWA when Boeing puts out a Service Bulletin? Do you wait for an Airworthiness Directive, or do you –– what is your experience with your operators in terms of that area? It may just be on an individual basis, I don't know.

WITNESS VANNOY: Well, when we put out an alert bulletin, we normally give the operators our recommendations in writing as to the urgency. We also usually tell them what we believe the FAA's intentions are.

I think in this case at the time of the accident most operators in the world had at least inspected some of their airplanes, and most everybody was complying with the recommendations of that bulletin. So, TWA wasn't totally unusual. They had not inspected all their fleet, and that was consistent with other operators.

So, when the Airworthiness Directive followed, of course it was mandatory, and not all airplanes had been inspected per that requirement.

MR. SWAIM: Mr. Vannoy, what is an Alert Service Bulletin versus a Service Bulletin?

WITNESS VANNOY: Okay, we publish an Alert Service Bulletin. It is a higher priority bulletin that is published on colored paper, where the regular bulletins are on white paper, and it is a higher priority, more urgent and normally signifies it has safety implications.

CHAIRMAN HALL: Was this an Alert one, or not?

WITNESS VANNOY: Yes, it was.

CHAIRMAN HALL: I got it on white paper. So, it was an alert?

WITNESS VANNOY: Yes.

CHAIRMAN HALL: So, Mr. Craycraft, do you know whether the TWA accident aircraft was inspected at the next opportunity in regard to this Service Bulletin 74728-A-2194?

WITNESS CRAYCRAFT: I do not know that we actually had the paperwork out yet to accomplish the bulletin. I don't have those facts here in front of me, sir. I can look and find out, but --

CHAIRMAN HALL: Okay, if you could provide that for the record, I would appreciate it.

WITNESS CRAYCRAFT: Yes, sir. We have adopted a policy within TWA that any Alert Service Bulletin coming from Boeing we considered the same as if it were a directive from the government.

CHAIRMAN HALL: Was that before or after the accident?

WITNESS CRAYCRAFT: That was before.

CHAIRMAN HALL: Before the accident?

WITNESS CRAYCRAFT: Yes.

CHAIRMAN HALL: So, this should have been treated as an AD?

WITNESS CRAYCRAFT: Yes, sir.

CHAIRMAN HALL: And the work should have been done?

WITNESS CRAYCRAFT: Well, I can't answer the timing.

CHAIRMAN HALL: Yeah. Did you find any evidence, Ms. Eckrote, that this inspection had taken place?

MS. ECKROTE: No, the inspection had not taken place. However, during my maintenance review TWA was in the process of completing a modification order in preparation for the Airworthiness Directive that was still being reviewed.

SO, they weren't just completely ignoring the Service Bulletin. They were going through the --

CHAIRMAN HALL: Well, I am not saying they were ignoring it. I am just trying to understand.

MS. ECKROTE: Right, they were still in the process of getting it into their system and it had not been completed yet at the time of the accident.

CHAIRMAN HALL: But, now, your -- the Maintenance Group's inspection, were there any other AD's or Service Bulletins that had not been –– where the work had not been performed on the accident aircraft other than this one?

MS. ECKROTE: A review of the records determined that all of the Airworthiness Directives that were applicable at the time of the accident had been accomplished.

CHAIRMAN HALL: With the exception of this one?

MS. ECKROTE: This --

CHAIRMAN HALL: Well, this was not an AD.

MS. ECKROTE: Right, this was a --

CHAIRMAN HALL: What about Service Bulletins?

MS. ECKROTE: Again, Service Bulletins aren't mandatory. We found some areas such as this one where the Service Bulletin had not been accomplished. In other areas the Service Bulletins had been accomplished.

CHAIRMAN HALL: Do you have in the record the Service Bulletins that had and had not?

MS. ECKROTE: No, I do have in my factual report a reference to the Service Bulletin that we are talking about right now and the fuel pump, and then the Airworthiness Directives are referenced.

CHAIRMAN HALL: Well, I think it would be appropriate for you to find out what the status was of the accident aircraft on all the Service Bulletins that were issued by Boeing because Mr. Craycraft said that they had -- they are equivalent to AD's as far as TWA was concerned.

MS. ECKROTE: I will look into that, yes, sir.

WITNESS CRAYCRAFT: Let me rephrase that, Mr. Chairman. That is Alert Service Bulletins, not all Service Bulletins.

CHAIRMAN HALL: Just the Alerts?

WITNESS CRAYCRAFT: Yes, sir.

CHAIRMAN HALL: Okay, well then let's be sure you clarify the difference between -- I apologize, Mr. Craycraft. I was given so many pounds of paper to read for this hearing, and I don't -- this is all on white paper, and I appreciate knowing the difference between the Alert and the regular Service Bulletin.

WITNESS CRAYCRAFT: I might help you a little bit on that. An Alert Service Bulletin has an "A" in the numbering system, such as the Service Bulletin you are referring to is 74728-A-2092. The "A" indicates that it is an Alert Service Bulletin.

CHAIRMAN HALL: Okay, other questions from the Technical Panel?

(No response.)

MS. ECKROTE: I don't think so. I think we are ready to get into the minimum equipment list issues.

CHAIRMAN HALL: Well, I want to get into this -- is anybody going to get into this one thing on the -- there is one other thing that was stuck in my memory, and that is on this shield, the work you did, Mr. Thomas, on the shield, the Service Bulletin that went out on the shield over the High-Z and Low-Z fire -- wiring for the fuel quantity system.

Can either one of you all help me on what -- what that was issued for and what -- if that has any significance?

MR. RODRIGUES: Mr. Chairman, Boeing -- the Boeing table?

CHAIRMAN HALL: Yes.

MR. RODRIGUES: I have heard that is the shield from the Madrid accident.

(Discussion off the record.)

WITNESS CRAYCRAFT: I think you are referring to the Service Bulletin that was issued after the Iranian accident; is that correct, sir? If it is, yes, that was an AD, and that was accomplished on that aircraft.

CHAIRMAN HALL: Well, I am referring to a letter from October 2nd from Boeing to Mr. Swain, and I will send it down and then -- while we continue. It says "FQIS wire shielding, TWA 747-100 accident near Long Island," and I don't see the exact date.

That may be it, but it came from Mr. Pervis, and I just wanted to -- it was a -- what got my attention was it was an action that was taken after the initial design. My question was, why was the shield -- why was the shield added, or would you rather just have the -- let me send this over, and then you can answer that later, then.

WITNESS CRAYCRAFT: Mr. Chairman, if I could ask a question for just a moment in your reference to the fuel pumps?

CHAIRMAN HALL: Urn-hum.

WITNESS CRAYCRAFT: Is that from the maintenance records of the sixteen items?

CHAIRMAN HALL: Yes.

WITNESS CRAYCRAFT: I believe that identifies the sixteen pumps that is in the aircraft and, so, there is an entry there for every pump in the airplane and its history on the airplane.

CHAIRMAN HALL: That's right.

WITNESS CRAYCRAFT: Not necessarily the removal time. It just goes back the full back history of when those pumps were installed and why.

CHAIRMAN HALL: Well --

WITNESS CRAYCRAFT: Some of them were for routine --

CHAIRMAN HALL: Let me say, Mr. Craycraft, I have -- there is nothing that has been presented to the Board through the maintenance study that indicates any concerns that I am aware of at this time in regard to the maintenance of the aircraft.

However, there are some things that I was trying to understand so that we could be sure that we cover all of this, and in reading all this material I noted, because we had a great deal of discussion about the probes and the wires, and of course the probes had wires and the wires run through various parts of the airplane, and we also have in the tank pumps -- and that was --

The purpose of my question was -- looking at the write-ups on the pumps -- was whether that was anything – anything unusual, or not. Was -- and that just kind of stuck at me, plus the fact that the -- that this was the only Service Bulletin that Boeing had -- I guess it was an Alert Service Bulletin that the Chairman is aware of that had not been performed, and I thought there should be some explanation on the record for what that was.

Again, we have no way of knowing whether that had anything to do or not with the TWA 800 tragedy. We are just trying to be sure that we cover each -- you know, each trail that we should.

WITNESS CRAYCRAFT: Yes, sir, and a quick review of those sixteen items, there are -- it has identified every pump on the airplane and the date it was installed, and at quick glance -- here is one, for example, that had been installed in 1991.

So, that goes back to a clear installation record of all of the pumps. So, that is why there is sixteen entries; there is one for every pump, sir.

CHAIRMAN HALL: No, I am talking about write-ups, not entries. But, you are telling me that when the pump is installed that is a write-up, as well?

WITNESS CRAYCRAFT: Yes, sir, that is an identification.

CHAIRMAN HALL: Okay, that's very helpful, because I don't want to have any mis-impressions on that at all. Well, you proceed into the MEL, and we will come back to Ivor and Mr. Thomas in a minute.

WITNESS THOMAS: I can answer that question now, if you wish, Mr. Chairman?

CHAIRMAN HALL: Yes, sir.

WITNESS THOMAS: This particular High-Z, Low-Z shield was added on line number -- around about line number 400. It was a concern about accuracy of the FQIS.

There was a five volt, light-dimming circuit. Mr. Hahn (sic) explained this yesterday. I will just refresh it. I am not an electrical engineer, so this will refresh your memory.

There was a five volt dimming system that for EMI reasons was applying a signal onto the FQIS wiring that was sufficient to cause a mild gaging system inaccuracy to show up, and we wanted to correct that. So, that was why that shield was added.

CHAIRMAN HALL: Now, does that have anything to do with the fuel flow indicator on this? That doesn't lead to the fuel flow indicator that was fluctuating at all?

WITNESS THOMAS: No.

CHAIRMAN HALL: That is all I was interested in. Okay, who's up? Mr. Wiemeyer, are we going to get you to actually ask a question? Please proceed.

MR. WIEMEYER: Thank you, Mr. Chairman. The next discussion is really not part of the aging aircraft, per se. It has to do with what we call the MEL, or minimum equipment list for an aircraft.

The general public becomes aware of items that pertain to a minimum equipment list as a result of an agent or a crew member generally making an announcement that the flight is going to be delayed because such and such has to be repaired.

The regulations permit certain items of equipment to be inoperative on an aircraft, and that aircraft may continue to operate for various lengths of time with that equipment inoperative.

I would like to start out by asking Mr. Crow if he would explain what the mechanism is with regard to minimum equipment list and how the minimum -- excuse me –– minimum equipment list was developed.

WITNESS CROW: I would be happy to address that, Mr. Wiemeyer and Mr. Chairman. In 1964 the Federal Aviation, through the Federal Aviation Regulations, authorized the use of the minimum equipment list for inoperable equipment –– instruments and equipment. The regulation -- without trying to sound bureaucratic, the regulation is FAR 121-628.

This contains all of the policy and some procedures for implementing the policy. Basically, it says, as you paraphrased, that a certificate holder -- and a certificate holder, Mr. Chairman, is an air carrier, anyone that is involved in the business of air transport, as a matter of fact.

But, they are authorized by this Federal

Aviation regulation to have certain instruments and equipment inoperable as long as the FAA, through the principal maintenance inspector, has issued as an authorization to that air carrier operations specifications D–95.

The operations specifications detail the limitations of the MEL, the time limits for which certain category items must be repaired, and it also gives a provision for a continuing authorization for MEL extension.

We issue this routinely to air carriers that have demonstrated through the certification process that they do, in fact, have all of the tools and equipment, personnel and parts along -- at specific points along its route to service its aircraft as a certification requirement.

We will maintain that Op spec as long as that continued authorization is met. Bureaucratically speaking, that is FAR 121-105 as it applies to domestic and flight operators.

The MEL concept is not a concept that is only in the air carrier industry. For many years the military has had delay discrepancy lists that correspond with our MEL program. In some cases they were more lenient, and in some cases they became more aligned with our MEL procedures.

In 1978 the FAA, through the same process of regulations, authorized 135 operators the same privilege, and in 1991 they allowed single engine operations with MEL privileges.

The process of developing an MEL starts with the manufacturer and the proposed operators when a new iteration of aircraft is being developed. The folk that are going to be flying the airplane and the manufacturer collaborate together using the best minds they have to identify those systems that have the redundancy to allow the aircraft to be operated to the highest degree of safety in air transportation, such as the Federal Aviation Act of 1958 described before it was remodified.

In doing that and presenting to the Aircraft Evaluation Group, and more specifically the Flight Standards Flight Operations Evaluation Board, people that have the ultimate responsibility for the management and revision of the MMEL, master minimum equipment list, they will provide that list that they have prepared to the FOEB Chairman.

When it comes from the manufacturer and the proposed users of that MMEL, it comes as a, quote, “proposed master minimum equipment list.” It is a working document that will continue to be used by the FOEB -- and I will use that acronym because it is easier to say, Flight Operations Evaluation Board -- the manufacturer, interested operators, other parties, specific people from the FAA and all three disciplines, operations, maintenance and avionics, and they will form a Board that will evaluate that proposed master minimum equipment list.

Before that master minimum equipment list is accepted and authorized – approved and authorized for use by the community, it must –– the Board must reach a consensus of opinion on all items that are allowed to be -- to be -- have equipment that is inoperable.

Once the FOEB approves that document, then it is sent to the Air Directorate in Washington, it goes on the MEL bulletin board and it is made available to the general public. It is made available to all of the air carriers where they can develop their own individual minimum equipment list.

Now, the minimum equipment list that the air carriers develop in cooperation with some of their vendors and manufacturers, et cetera –– and this information flows to them from the manufacturer. Boeing, in fact, provides some support to its operators of its airplane in the form of a dispatch deviation guide that helps them identify maintenance and operations activities that must be accomplished before the airplane can be dispatched.

But, once this MEL is put together by the operator, the principal maintenance -- principal operations inspector has the final authority for that MEL document. Before he or she would approve that document, it would be a coordinated effort between all three principals on there that have certificate management responsibility for that air carrier.

Once they reach a consensus on the operator and the certificate holder's MEL, then it would be approved. At that point, as a Principal Maintenance Inspector, I would initiate and authorize that operator to use that minimum equipment list.

So, it has been around a long time, it is developed in the interest of safety and to allow the air carriers to have some dispatch reliability, and in the highest interest of safety to operate the aircraft it has system redundancy to perform and do the job it is intended to do in air transportation.

MR. SWEEDLER: Excuse me, Mr. Crow. Could you just give us some examples of the type of equipment that can be inoperative and the airplane still be allowed to operate?

MR. CROW: Yes, sir, I will try to speak to that, Mr. Sweedler. The Boeing 747 master minimum equipment list is a list of items of two –– excuse me -- 299 pages. This includes -- this includes the title page, the table of contents, the list of revisions, the list of effective pages, a short summary of each one of the changes that occurred to the MMEL, the definitions which is quite extensive -- several pages, eight or nine pages –– and the preamble to the MEL .

The remainder of it is standard ATA Code 100 items that are listed as part of the systems on the airplane that have been agreed upon by consensus that can be deferred. There are many items.

MR. SWEEDLER: But, I was interested in an example. Give us an example of a half a dozen items.

MR. CROW: One classic example would be a boost pump. The fuel tanks have the redundancy. Most of them have at least two boost pumps. Some may have more depending upon the aircraft that you may be talking about.

Because of the redundancy and because the inerrant level of safety is still present with a boost pump inoperative, that aircraft may be dispatched in some cases, in accordance with its individual MEL and the MMEL, with the boost pump inoperative.

There are other things. There are typically three -- there are four classes, Mr. Sweedler, of items by time category.

We have a Category A item which must be repaired in accordance with the FAR, or any other approved document that limits how long that item can be inoperative .

We have a Category B item that will allow you to operate with that particular item inoperative for 3 days. You have a Category C item that will allow you to operate the aircraft with that particular item for a period of 10 days. You have a Category D item that would allow you to operate the airplane for 120 days.

I spoke earlier to a continuous authorization for MEL extension, and those only apply to category B and C items, because Category A items are defined by the FAR or other approved documents. Category D items are typically cabin convenience items and administrative items.

MR. SWEEDLER: How about an example of a piece of equipment that would fall in each of those four categories?

CHAIRMAN HALL: Go ahead, and then let’s move on, Mr. Sweedler.

MR. SWEEDLER: Okay.

WITNESS CROW: Category D items would be items that –– well, I am trying to make reference to some that I really know about rather than trying to draw some from the 747 MMEL.

Category A items might include those things such as –– depending on a particular type of operation, and I will try to keep this very simple. If a person was going to operate the aircraft in a VFR environment only, visual flight rules environment only, day time, he may be authorized to operate that aircraft without navigation lights, and the operative word is "may," depending on the individual MEL.

The Category B item could be -- depending on the MMEL, could be a fuel system component. It could be a piece of navigation equipment, or a Category C item could be similar to the same.

Category D items typically put themselves in the position of cabin convenience items or other items that do not affect the airworthiness of the aircraft.

MR. SWEEDLER: Thank you, Mr. Crow.

WITNESS CROW: Yes, sir.

MR. WIEMEYER: Mr. Crow, who actually develops the items on the minimum equipment list?

WITNESS CROW: The manufacturer and proposed operators will develop the proposed master minimum equipment list for delivery to the FOEB, and then the FOEB has the responsibility and accountability for the management and revision of that document.

MR. WIEMEYER: If you would, please, briefly detail when a discrepancy is found the process that that discrepancy goes through and who looks at it, who makes decisions and who is responsible for the application of a minimum equipment list.

WITNESS CROW: Well, typically the discovery of discrepancies could come from two different places. One, a pilot report which we refer to as pi–reps, or it could be from a maintenance person working on an airplane that is an in service airplane.

An in service airplane is an airplane that is eligible for dispatch. An out of service airplane is one that is in extended maintenance or inspection. So, typically, if you have an in service airplane –– and this is the only place that you would be concerned about dispatchability –– it would typically come from a pilot write-up, or from a maintenance discrepancy discovered during one of the lesser checks, like a PS Check or something of that sort.

Once the maintenance folk in debriefing with the Captain and understanding the discrepancy, or on their own initiative by finding a maintenance discrepancy discovers that, then that information is passed on through the maintenance control processes of each air carrier.

It finally ends up in the Dispatch Center where the aircraft dispatcher has the responsibility to notify the flight crew that there is an item of inoperative equipment or instruments, and that they make a determination as a dispatcher in concert with the flight crew and put that information on the dispatch release.

It is incumbent upon the Captain of the aircraft or flight crew member that when they do have an item it is MEL'd. Generally, you will find that the flight crews will check their minimum equipment list that they are required to have with them either in printed form or in another form to determine the limitations of that MEL'd item before they depart.

MR. WIEMEYER: Okay, and my final question in this area is what kind of latitude does the operator and the principals for the FAA have in working within the minimum equipment list? Can they change it and, if so, how much? -- and that type of information is what I am looking for.

WITNESS CROW: Well, first of all and most foremost, the operator's MEL cannot be less restrictive than the MMEL. The Principal Operations Inspector having the final authority for the development and the approval of the operator's MEL can within certain limitations approve changes to the operator's MEL as long as it is less restrictive than the master minimum equipment list developed and approved by the FOEB.

MR. WIEMEYER: That brings up one final question. The time limits that are placed on each category, how are those arrived at?

WITNESS CROW: How are they arrived at?

MR. WIEMEYER: Yes.

WITNESS CROW: They are identified in the preamble to the MMEL and the MEL. These are longstanding provisions that have been in place, and I would suggest to you without specific knowledge that they have been there since the 1964 era.

MR. WIEMEYER: But, you don't know the rationale behind their development?

WITNESS CROW: Well, because certain things have more criticality than others, and it is important that the air carriers take action to return the aircraft to its full top certificated status at the earliest opportunity.

An MEL item or a CDL item -- and I may

discuss that -- are actually a revision to the type design, but no further approval is required in order to do the -- to exercise the MEL provision.

MR. WIEMEYER: Okay, thank you. I would like to turn the questioning back over to Ms. Eckrote now to deal with the specifics of the aircraft involved in the TWA accident.

MS. ECKROTE: Thank you, Norm. I have some questions for Mr. Craycraft. Mr. Crow did answer some of the questions I was going to ask. I would like you to kind of more detail TWA's procedures as far as what are your procedures when an item of equipment is recorded inoperative, or a system is reported inoperative?

WITNESS CRAYCRAFT: Well, the first procedure is that if an item becomes inoperative, it is obvious to the flight crew that they have something that is not working properly, so they make an entry in the aircraft log book. So, that is step one.

Step two, then, is it arrives at a station and the maintenance personnel there have the opportunity to either repair that item, if they have the opportunity, or if they don't have the time to repair it or the equipment to repair it, they may apply the MEL application to it.

In the case of the accident aircraft, it had four open MEL's on it. If you would like, I would just go ahead and go through those items.

MS. ECKROTE: Yes, if you would, please, and I think that will help Mr. Sweedler in identifying exactly what an MEL is. Would you please identify it, and then what the procedure or penalty is for each of those items?

WITNESS CRAYCRAFT: Yes, sir. These -- three of them happen to be Category C items, and Category C, to remind you, is a ten calendar day item that the MEL permits us to operate that aircraft. That is the time limit.

Obviously, our intent is to restore the aircraft to its full configuration at the first opportunity, but many times we are on a very tight turn schedule to get the airplane flying and we like to allow the aircraft to an overnight maintenance where we can conveniently repair the item.

The first item is a number three engine thrust reverser malfunction, and that problem developed on July the 7th at Tel Aviv, and they replaced a pneumatic drive motor for the thrust reverser, and that didn't fix it.

so, then the airplane then flew under the auspices of the MEL, and then JFK replaced some flex drives cables that had been sheared, and that still didn't fix the item, so the item remained under the MEL auspices. So, that was carried on.

But, the item obviously has to have the concurrence of the maintenance coordinators to be carried on an MEL. It is entered into our AMPS system and is tracked by the AMPS, and that is what it is.

Now, with the thrust reverser there are some penalties involved, and some interacting activities that the reverser may be inoperative, and only one on the aircraft of which there is four reversers, obviously, and only one can be inoperative, and it can only be inoperative provided the anti-skid system, the auto-spoiler systems are operating normally and that there is no damage on the thrust reverser which would impair the structural integrity of the thrust reverser.

So, it isn't just a carte blanche that we can go with the reverser inoperative. We have to do some inspection and some procedures and assure that other items on the airplane that could affect the function of the aircraft are verified, also.

Likewise, they have to lock the thrust reverser in the forward thrust position so that it cannot inadvertently deploy and cause greater problems.

CHAIRMAN HALL: You might, if you wouldn't mind, Mr. Craycraft, sort of tell us what the function of the thrust reverser is, for those that might not be familiar with it.

WITNESS CRAYCRAFT: Okay, I am sorry, I am too used to airplanes. The thrust reverser is a device on the engine that when the flight crew land the aircraft and the gear are firmly on the ground, they can extend reversers.

On our airplanes we only have fan reversers. The airplane as it was originally delivered had fan and turbine reversers, but we deactivated our turbine reversers and just have the fan reverser. That is up around the front end of the engine.

There is a sleeve that slides back around the engine, and then there is blocker doors that come in behind the fan air exit area and deflect the thrust of the fan blades forward to reduce the forward speed of the aircraft after the aircraft has landed. Is that satisfactory?

Another item was an oil quantity on the number three engine, and I forgot to say that was number three engine on the thrust reverser. On an oil quantity being inoperative, you have to service the engine full with oil each time before the aircraft is departed. So, that is the penalty that is involved there, and that item was still an open item when the aircraft left JFK. That is a C item, also.

Another item was the number three left leading edge flap amber light stayed on when the leading edge flaps were up, and that is a C item. That was entered on July the 15th, and it was still an open item. They had checked it and verified that the leading edge devices were operating properly, but it was just a light malfunction.

The other item is likewise a check -- a Category C item, and it was on July 17th in Athens. Going into Athens it was reported that the Captain's weather radar indicator was inoperative. So, Athens dispatched it, part of the MEL.

There was another weather radar on the aircraft so that they did have weather radar coverage. SO, it was no operational penalty to dispatch with one weather radar indicator inoperative.

We had one CDL item, and I don't know that the CDL was described in the extent that the master MEL, but that is -- configuration deviation list is what a CDL is, and we had one item that on July the 4th, at Madrid we had a left hand canoe ferring for the number two trailing edge flap.

When you -- that perhaps needs some discussion of what is a canoe ferring, and if you have seen a 747 and you look out there under the trailing edge flaps, there is a huge device that looks like a canoe. That is actually a ferring to cover the structural aspects of carrying the flap carriage.

SO, that is a canoe ferring is what it is referred to, and it may be inoperative and –– or, may be missing from the aircraft, and there is a runway penalty for operating with that ferring off of there. SO, that, likewise, the crew would have to be advised of these things, of every MEL item.

The instrument or indicator in the cockpit that is inoperative has a placard on it so indicating it is inoperative. There is a placard that is installed on the aircraft log book that identifies what the write-up actually was and why that is inoperative, and then it is transferred to what is a deferred maintenance page in the aircraft log book where it is carried until it is corrected, and it is entered into the AMP system which I mentioned earlier that tracks all of the aircraft log items, including the ones that are not corrected.

SO, whenever an aircraft comes to a station its work is performed. An open item AMPS sheet is sent to that station. Then they have the opportunity to work on it, or -- as manpower and material are available to correct the items.

CHAIRMAN HALL: Very well, and one last clarification. Maybe you could tell us again what a CDL is versus an MEL and what the difference is.

WITNESS CRAYCRAFT: Configuration Deviation List is what CDL is. That means that it is a -- it is primarily structural ferrings and that sort of thing where it is something that is deviation from the configuration of the aircraft, whereas a master MEL -- that is the master MEL, MMEL -- and we use the term master equipment and dispatch procedures book within TWA for our maintenance people, and that is where we have the list and the procedures for following the utilized -- the MEL item.

The flight crews likewise have an MEL in their flight hand book, but they don't have the maintenance procedures that must be accomplished when we dispatch an aircraft with an MEL item.

CHAIRMAN HALL: Okay, thank you.

WITNESS CROW: Mr. Chairman, I just want an addendum to what Mr. Craycraft had said. For the record, the CDL is not a part of the MEL. Many operators place it there for the convenience of the operators, but the CDL is actually an addendum to the approved flight manual, and typically there is where it is placed.

CHAIRMAN HALL: Thank you.

MS. ECKROTE: Mr. Craycraft, what procedures are in place if the MEL item cannot be accomplished or fixed in the appropriate time period?

WITNESS CRAYCRAFT: Within the procedures and with the regulation it allows that in unusual circumstances where the repair time limits described cannot be met, it is possible to extend the repair deadline under controlled conditions.

These time extensions, and I think Mr. Crow referred to that, apply only to Category B and C items. Before we consider an MEL extension item, it is our Maintenance Coordination Group that has the responsibility to assure that all reasonable efforts and possibilities for correction have been extended before we apply for extension of the MEL.

When I say apply for an extension, the extension is really granted by one of our staff members in the Maintenance Department. The requirement is to provide that MEL extension item to the FAA within twenty-four hours, upon which the FAA can then review it, and when I say FAA, the Principal Inspector holding the certificate, he reviews it and if he concurs with it then we have the extension that we requested. He has the prerogative of refusing the extension, at which time the next time the aircraft lands, that's where it sits until it is repaired.

MS. ECKROTE: Thank you. Mr. Crow, is there anything you can add to that, or is that definition adequate?

WITNESS CROW: I think Mr Craycraft is doing an excellent job explaining that, and I appreciate that.

MS. ECKROTE: Thank you. I have just one last question for Mr. Craycraft. Who has the ultimate responsibility to determine that the flight can be conducted in a safe manner under the flight conditions anticipated using the MEL?

WITNESS CRAYCRAFT: Well, ultimately it is the Captain's responsibility to determine that there is nothing on the aircraft that he -- when he takes the aircraft, it is his responsibility to assure that everything is there.

Of course, certainly maintenance is in no way attempting to deter from safe operation of the aircraft when we ask the crew to take an item on MEL.

MS. ECKROTE: SO, in a case on the departure of Flight 800 when we had four MEL items and one open CDL item, you know, is it the Captain's responsibility to also make sure that the interrelationship of those systems won't interfere with the safe operation of the flight?

WITNESS CRAYCRAFT: Yes. Of course, it certainly is a maintenance responsibility to begin with. We don't place the flight crew in that sort of a situation, but ultimately, yes, it is the flight crew's responsibility. He is the one that accepts the aircraft. I might add, if he chooses not to take an item under MEL, he has the prerogative also.

MS. ECKROTE: How does the flight dispatcher fall within all of this, his responsibilities?

WITNESS CRAYCRAFT: I am not involved in the flight dispatch aspect, so I really can't answer that.

MS. ECKROTE: Okay, thank you very much.

CHAIRMAN HALL: Now, Mr. Craycraft, I have one question. On page 21 of the systems report at the top of the page. I think we should clarify this. It says, "After the accident on July 17th, 1996, a mechanic reported to the National Transportation Safety Board Operations Group Chairman that during the fueling process for Flight 800 at JFK the fuel system shut down."

"The mechanic reported that the circuit breaker was pulled and the pressure fueling process was continued. After the fueling was complete, the circuit breaker was reset. The mechanic reported that an entry in the aircraft maintenance log book was not made prior to the departure of the flight."

I was wondering if you could tell us, since this involved the fueling of the aircraft before the accident flight, you know, if you could explain that process to us. Was that something that should -- in any way was impacted by the MEL, the CDL and should there have been an aircraft maintenance log book write up on that incident, or item?

WITNESS CRAYCRAFT: Yes, there should be, because anytime there is a malfunction on the aircraft it is supposed to be recorded in the log. That is the first answer to your question.

Secondly, a reviewing on page 20, also it is making reference to difficulty with the aircraft with fueling, and without knowing specifically what happened on that incident, but this -- I would go back into the volumetric shut-off system which was described by Mr. Taylor, I believe of Honeywell, since they make the volumetric shut-off system.

But, that is really where the nub of the problem was on this particular aircraft, that the volumetric shut–off system has the capability of shutting down the fueling on the aircraft. A fueler will normally go out to the wing, open up the wing panel, connect his hoses, of course statically ground his fuel truck to the aircraft and to ground, and begin fueling.

Power is applied to the wing fueling panel when he opens the door so that he can open the fueling valves to permit fuel to go from the fueling manifold into the individual tanks. He has a switch on the panel for each individual tank to control where the fuel is going that he is putting into the aircraft.

The volumetric shut–off system was a device that will shut the system down if he were not paying close enough attention and tried to put too much fuel in the airplane and –– but, it likewise has the capability that if some malfunction occurs it could shut it down at any time. I think that was what was happening on this airplane. We were having some difficulty in the vol shut-off system that was shutting the fueling down.

CHAIRMAN HALL: The system, Mr. Vannoy or Mr. Thomas, the wiring for that system, where does it run?

WITNESS VANNOY: I don’t think either one of us has the specific answer for you, Mr. Chairman.

CHAIRMAN HALL: Do you know, Mr. Swaim?

MR. SWAIM: Yes, sir, we will have that up here in just a second.

(Slide shown.)

United States Information Agency. There we go. The volumetric shut-off runs commonly between the electrical compartment and the flight deck of the right side at about station 360. That is the orange line running up under the cockpit there. Up from there to the cockpit.

CHAIRMAN HALL: Okay, well, does it run parallel with any of these other things we have discussed, the FQIS, the indicator for the four -- number four fuel flow and --

WITNESS VANNOY: In that short portion of the run you have the blue line which is the fuel flow wiring coming in from the wing. It goes to a computer down there in the E&E which happens -- see that right near the electrical equipment center which happens to sit right near the volumetric shut-off computer, and from there they are routed together up to the flight deck through that orange wire -- that orange line.

CHAIRMAN HALL: Mr. Craycraft, as you alluded to, on page 20 of that report it says that the aircraft maintenance log book entries from July 1, ’94 through July 17th, ’96, which is over a two-year period of time, so I want to be sure –– indicate that “the aircraft experienced several intermittent problems not accepting fuel. In most cases the aircraft was pressure-fueled and the action was deferred, ” and then it lists those items.

Is this something that you have to deal with in a maintenance situation, and is it related to the age of the aircraft, or is this just a common problem with the 747?

WITNESS CRAYCRAFT: Well, my first response, it is not related to age because we have had –– at various times have had difficulty with the volumetric shut–off system on the aircraft. But, in terms of comparing this aircraft to others in the fleet, I have not made a comparison such as that, and there are others, my compadres that are responsible for the fuel quantity in that system.

CHAIRMAN HALL: Well, if there is anything else that TWA would like to put on the record in that regard, please supply it.

Mr. Thomas, what has been Boeing’s experience with this volumetric problem which Mr. Craycraft says is -- I don’t want to characterize what Mr. Craycraft said exactly, but indicated was some problem?

WITNESS THOMAS: I am aware that occasionally we do have problems with the volumetric top-off. There was a question posed last night. The gaging system is basically a mass indicating system. It is measuring how many pounds of fuel on board the airplane.

Obviously, the tank itself has a finite number of gallons of volume that it can take, so the volumetric top-off system has to in effect convert the mass indication or information coming from the FQIS into a volume, and then keep track of how many volume is in the tank and shut off the tank before the volume is exceeded.

So, it is basically a conversion from pounds of fuel going into the tank to how many gallons of fuel is going into the tank.

CHAIRMAN HALL: So, the end of this is in the tank itself?

WITNESS THOMAS: It is the gaging system. There is a signal coming from the gaging system, which is pounds.

CHAIRMAN HALL: Well, what could have caused this problem? What are the various things that can cause this thing not to work?

WITNESS THOMAS: I am not enough -- I am not familiar with the exact details. It could be a -- there is a compensative problem, or a loss of signal into the volumetric top–off system where it would say I don't know how many gallons have gone into the tank, therefore I will shut the system down.

It is a fail-safe system. It would say, if I don't know what is going on, I will signal the system to shut down, and the mechanics have the option of bypassing the volumetric top-off system and basically watching the gages very carefully and stopping the fuel when they get the right amount manually. They have a switch at the refueling station.

CHAIRMAN HALL: Okay.

WITNESS THOMAS: I don't know the details of the specific event, but that is typically what --

CHAIRMAN HALL: What type of wire is used to that system?

WITNESS THOMAS: I personally have -- I do not know, sir.

CHAIRMAN HALL: Mr. Taylor, if you could find out and provide that for the record, I would appreciate it.

Any other questions from the Technical Panel before we move to the parties?

MR. SWAIM: Yes, sir. Questions come up

about fuel indication discrepancies. It is -- in Ms. Eckrote's Exhibit 11-A, pages 22 and subsequent, there are several pages of write-ups on fuel flow indication problems, gages that were placarded "inop" or gages that were inaccurate, and I was wondering if Mr. Craycraft could discuss what -- at least in those two areas, what are the typical write-up and response as far as if you have to placard it, and the typical response for an inaccuracy of the fuel gage?

WITNESS CRAYCRAFT: I am sorry, Bob, I really haven't had an opportunity to review the information. I wasn't prepared to look at the fuel quantity aspect of what the malfunctions were there.

I had looked at the fuel flow, since that has been kind of a hot topic to discuss, and there was one item where -- I am looking at page 24 of the report, the bottom item where the mechanic quoted as suspecting wiring.

But, if you continue on looking in that report, that was -- a fuel flow transmitter was the culprit there, the device - the transmitting device on the engine which caused the malfunction on that. So, but in terms of saying typically what is a fuel quantity, I would need to go back and review the data and provide that to you.

MR. SWAIM: Would you please? We would like to know how it is placarded. Actually, could you at least discuss that side of it? If something is placarded inoperative, if it is inaccurate and they placard it, how would they do that?

WITNESS CRAYCRAFT: Well, the placard is put on the gage at the flight engineer's station to indicate that that unit is inoperative, and if I could use the terminology that we use where for an ADL item, for an aircraft item, that if the item is not performing its intended function as it is supposed to it must be considered inoperative.

SO, even though it may be reading, and reading inaccurate, but as far as our terminology is concerned that is inoperative and we would placard it that way and carry it per the MEL. I believe -- I don't have that page of the MEL, but that only one indicator per aircraft can be inoperative.

MR. SWAIM: Now, when they do that, do they pull the circuit breakers, or somehow further sever or cut off power to that system, or just simply put the label "inop" on the indicator?

WITNESS CRAYCRAFT: I believe there is only one circuit breaker that feeds the entire fuel quantity system, so they could not pull the circuit breaker.

They would now only have to just leave that in and placard that item.

MR. SWAIM: Very well, thank you.

CHAIRMAN HALL: Any other questions from the Technical Panel?

(No response.)

If not, I believe we are back at Crane Company Hydro-Aire. Do you have any questions for these witnesses?

MR. WIEMEYER: Thank you, Mr. Chairman. Crane has no questions.

CHAIRMAN HALL: Thank you. Now the International Association of Machinists and Aerospace Workers, the people that actually perform the work that we have been talking about all afternoon, do you have any questions for these witnesses?

MR. LIDDELL: Mr. Chairman, yes, we have just one question for Mr. Swaim. Could you inform us as to the age of the Philippines 737 that had the center tank explosion? The relative age, not specific.

MR. SWAIM: Actually, I didn't work that accident, but Mr. Haueter did. Maybe he can answer it.

MR. HAUETER: That airplane is approximately six years old. It is a 737 300 series. It was fairly new at the time.

MR. LIDDELL: Thank you.

MR. RODRIGUES: Mr. Chairman, Boeing?

CHAIRMAN HALL: Yes.

MR. RODRIGUES: I believe that it was six months old, Tom.

CHAIRMAN HALL: Well, let's -- we have got the report in here. Let's find out for sure. We don't want to have any incorrect information here on that matter.

(Pause.)

I thought I saw the 737 report in here, didn't I, Deb? Where is it?

(Pause.)

Singapore accident, O'Hare accident, Madrid accident.

MR. SWAIM: It should be in Exhibit 9(d).

CHAIRMAN HALL: Here it is.

(Pause.)

Well, this is your registration number E1BZG, a Boeing 737 300 aircraft. Does Boeing have the information on how old it is? I will be glad to accept that if you do. I don't --

(Pause.)

1 don't see it right here in the report. This is, I might point out, a report of the Republic of

the Philippines Department of Transportation and Communications Air Transportation Office. The National Transportation Safety Board was a party to this investigation. We did not conduct. We were not the lead agency on the investigation.

(Pause.)

Well, let's -- we will come back and correct the record on that so we are sure once we –– Mr. Pervis is usually a fountain of knowledge. I am sure he must know, either he or Mr. Dormer.

Yes? Did you know, John, the age of the aircraft?

MR. RODRIGUES: Less than six months.

CHAIRMAN HALL: Less than six months? Okay. We will get the exact time on it, but Boeing represents that it was -- the aircraft was less than six months old when the accident occurred.

MR. LIDDELL: I have no further questions, Mr. Chairman.

CHAIRMAN HALL: Thank you. Trans World Airlines, Inc.? Captain?

CAPTAIN YOUNG: Thank you, Mr. Chairman. I have a question for Mr. Swaim. The Alert Service Bulletin that the Chairman was referring to I think in the center tank refers to the jettison override pumps, is that correct?

MR. SWAIM: It was a question for somebody else and I didn’t pull it out, so I don’t have it.

CAPTAIN YOUNG: But, I think it does --

CHAIRMAN HALL: Yeah, I think it was, yeah.

CAPTAIN YOUNG: It refers to the jettison override pumps and we did recover both of those pumps, I believe, is that correct?

MR. SWAIM: Yes, we did. One did not have the connector, though.

CAPTAIN YOUNG: Okay, but the pumps themselves, did you find any deficiencies when you inspected the pumps?

MR. SWAIM: Thanks to help here, yes, it is that Service Bulletin, and we saw no evidence of that sort inside the pump, inside the motor housing when we took it apart.

CAPTAIN YOUNG: So, there were -- you found no deficiencies, basically, with the pump then, I assume?

MR. SWAIM: You are asking me a very broad analytical question, or for a broad analytical response.

CHAIRMAN HALL: Well, there is nothing in the report right now that indicates we know anything is wrong with the pump?

MR. SWAIM: At this point, that is correct.

CHAIRMAN HALL: Well, then, you know, if I am going to bring it up and discuss it, Captain, I am glad you pointed that out. I should have done that myself, thank you.

CAPTAIN YOUNG: Yes, sir, and just you mentioned on the record for the volumetric shut-off procedure on page 21 of Mr. Swaim's systems report, it discusses --

MR. SWAIM: It is Debbie Eckrote's.

CAPTAIN YOUNG: Oh, I am sorry, it is Debbie Eckrote's report. I apologize, sir. It is on page 21. It has the maintenance manual reference for the fueling with the problem with the volumetric shut-off, so it is in the record. Thank you very much.

CHAIRMAN HALL: Well, thank you. This was a volume of material to go through, so is there anything else that you want to clarify on this, because I want to be sure -- I think Mr. Craycraft has done an excellent job, but I -- is there anything else that you have got, Captain?

CAPTAIN YOUNG: No, sir. I just wanted to make sure it was in the record.

CHAIRMAN HALL: Okay, thank you. The Federal

Aviation Administration? Mr. Streeter?

MR. STREETER: Yes, Mr. Chairman. First of all, for Mr. Crow. During your earlier testimony you used –– you used the term "probable cause," and the Chairman reminded me during the break that the term "probable cause" has a very, very definite legal meaning to the members of the Board, and it is something that doesn't occur until out at the end of the investigation.

Would you expect the FAA to respond quickly to any confirmed NTSB finding that affects safety regardless of the status of the probable cause?

WITNESS CROW: Well, the single word answer to that is yes. I think the FAA Flight Standards Air Certification Service would all respond immediately to any recommendation that was appropriate and germane to solving the problem and increasing safety in air transportation.

MR. STREETER: All right, thank you sir, and I would ask the Chairman if that --

CHAIRMAN HALL: That clarifies it for me. Thank you, sir.

MR. STREETER: All right. Thank you very much, sir. Mr. Taylor, Mr. Loeb asked a question earlier about whether or not any Air Force –– he didn't ask the question of you, but he asked whether any Air Force airplanes had polyex wiring, and I was wondering if you could answer that question?

WITNESS TAYLOR: Not to my knowledge. The United States Navy used polyex.

MR. STREETER: Mr. Vannoy, speaking of --

CHAIRMAN HALL: I am just confused. So I can understand this, doesn't the Air Force operate Boeing military equivalents of the 737 -- some of these equivalents, and are you saying there is different wiring in the military version and the commercial version?

WITNESS TAYLOR: The 747's that the -- first of all, the polyex wire was used only on the 747 airplane. Some of it was installed as mission equipment on AWACS airplanes, not as the aircraft wide, but it was only used in the general fleet on the 747 airplane.

CHAIRMAN HALL: Are there any military Air Force 747's that are classics that use a different type of wiring?

WITNESS TAYLOR: I can't answer that question. I don't know what has happened to --

CHAIRMAN HALL: Yeah, well, if you could just find that out for the record. I just, you know.

WITNESS VANNOY: Mr. Chairman?

CHAIRMAN HALL: Yes?

WITNESS VANNOY: Bob Vannoy here. The 747's used in the military, the -- like the E-4 airplanes, the earliest line number they have is around 200, so we stopped using the polyex wire sometime before that.

CHAIRMAN HALL: Okay.

WITNESS VANNOY: SO, I think that is your answer.

CHAIRMAN HALL: Good, thank you.

MR. STREETER: Mr. Vannoy, on the SSID'S on the 747's and other Boeing airplanes, I want to clarify. Are these static documents or are they updated as new information becomes available out of your inspections?

WITNESS VANNOY: That is a true SSID item, and actually it comes out of the document and is no longer a part of the program and has its own Service Bulletin and Airworthiness Directive and applies then to all airplanes.

We also update those documents approximately every couple of years, or depending on, you know, how much has changed or whatever. With new techniques, new alternatives for the operators that they request, and sometimes new pieces of structure are added, and also the sample fleet has changed, you know, and as airplanes go out of service or no longer become available for the inspections, we have to keep adding in more airplanes to keep the sample at a reasonable size, so there is a continual revision.

Right, every time we have a revision there will be also a new Airworthiness Directive that mandates that revision.

MR. STREETER: Thank you, sir. Mr. Slenski, you showed one picture of a mechanical failure where the insulation was worn off of the wiring. Do you know if that was found during normal inspection procedures?

WITNESS SLENSKI: On that particular case, actually I was present when we were doing some just general inspection on aircraft wire and we came across it in visual inspection.

MR. STREETER: Okay, and then I believe you also mentioned that the majority of that type of damage occurs - what was it? -- within six inches of the connectors?

WITNESS SLENSKI: Typically, and I think Mr. Crow made references, too. It is within about twelve to six inches of your connector because that is typically where the connectors are moved most often when you are moving avionics. It is handled.

MR. STREETER: All right, thank you, sir. Mr. Craycraft, regarding that statement about most of that damage being seen very close to the connectors, would you normally expect that a TWA mechanic, when he was installing or removing a piece of equipment, that he would inspect the wiring around and near the connectors?

WITNESS CRAYCRAFT: Yes, sir, I would expect him to do that.

MR. STREETER: All right, and Mr. Crow, based on your A&P background and working other certificates and your military background, would you expect an A&P or a military mechanic to examine those areas?

WITNESS CROW: I would expect an A&P mechanic to look at those very significantly, because the more opportunity you have for removal of those connectors and to bend and to twist and move wire, perform maintenance, the likelihood of damage increases.

SO, in every case my expectation would be that there would be a very good visual examination of that wiring.

MR. STREETER: All right, thank you, sir. Mr. Craycraft, if I could refer you to Exhibit n(a), if you have it there; that is, the Maintenance Group Factual Report, and in that exhibit on page 30.

(Pause.)

The top of the -- about one paragraph down there it has the paragraph -- at least on mine -- labelled paragraph 6 here and is the Aircraft Maintenance Log dated July 7th.

WITNESS CRAYCRAFT: Yes.

MR. STREETER: Okay. Now, that goes to the oil quantity, I believe, the oil quantity gage?

WITNESS CRAYCRAFT: Yes, sir.

MR. STREETER: And that is the MEL item that you discussed earlier, and you mentioned that one of the requirements of the MEL was to insure that the oil tank was serviced completely prior to departure.

I am not familiar with TWA's MEL, but also in the second paragraph in that section it states that in addition that there can be no evidence of above normal oil consumption or leakage, that the oil pressure indicating system must be functional, that the low oil pressure warning system must be functional and that the oil temperature indicating system must be operating normally and be monitored.

Assuming that that is all correct out of TWA's MEL, is this –– is this just a sign of even additional redundancy, and I know –– are all of these items required in addition to topping off the oil tank?

WITNESS CRAYCRAFT: Yes, sir.

MR. STREETER: All right, thank you very much. That is all I have, Mr. Chairman.

CHAIRMAN HALL: Boeing Commercial Airplane Group?

MR. RODRIGUES: Boeing has no questions, Mr. Chairman.

CHAIRMAN HALL: The Air Line Pilots Association?

CAPTAIN REKART: The Air Line Pilots Association has no questions, sir.

CHAIRMAN HALL: Honeywell, Inc.?

MR. THOMAS: Honeywell has no questions, Mr. Chairman.

CHAIRMAN HALL: Thank you. Do any of the parties have additional questions for these witnesses?

(No response.)

Does the Technical Panel have any additional questions for these witnesses?

(No response.)

If not, Mr. Sweedler?

MR. SWEEDLER: I have no further questions, Mr. Chairman.

CHAIRMAN HALL: Dr. Ellingstad?

DR. ELLINGSTAD: Mr. Vannoy, you had

introduced us to the notion of damage tolerance in relation to structures and talked about the concept of crack growth in structures in relation to that.

Is that same concept relevant to the systems area, and is there an analogue in electronic systems to crack growth?

WITNESS VANNOY: Well, I don't think there is a relative similar process in the systems area. I think in the systems area we do the very elaborate checks, fault assessments and what we call FMEA evaluations for each system to assure that things like single failures will not be more than -- or, disable one particular item.

SO, there is an extensive analysis done on systems, but it doesn't really have a similarity to crack growth.

DR. ELLINGSTAD: But, no solutions that can be achieved through some kind of inspection?

WITNESS VANNOY: I think in the systems area the various attributes we have discussed here, the way the systems are designed, the way they indicate their faults and the constant maintenance puts them in kind of a separate category, and I think the main area that we have to focus on is where we have the latent faults in systems, and by definition we can't tolerate those and when we find them we fix them.

So, I think the area that we are getting into now is we are going out and looking for latent faults that we heretofore have not thought about. I think that is really the next step, or that is the approach that possibly has to be taken.

DR. ELLINGSTAD: Mr. Slenski, do you have a comment on that area?

WITNESS SLENSKI: Well, the question, if I understand it, can we apply some of these principles using fault tolerant system design philosophy and -- I think, as I mentioned in my presentation, many of our concerns are the electromechanical type systems, and you can apply some of these principles.

As an example, the solder joint. You can predict crack growth in a solder joint. You can predict oxide growth on contacts, on surfaces. So, there are mechanisms we have.

It is very complex because you have the electrical and structural aspects, and I don't think we have arrived at the point where we can develop these predictive models yet, although there is research in those areas. So, it is possible if you consider all these complex interactions.

DR. ELLINGSTAD: Okay, Dr. Dunn, are there activities that the FAA is doing to further this kind of research that Mr. Slenski is talking about?

WITNESS DUNN: I am not specifically familiar with research that he has mentioned.

WITNESS SLENSKI: Well, if I can add, many of our major contractors are working in these areas. Obviously, I think it is more in the research arena at this time. I think there is many organizations supporting that research; the Air Force, all the military.

I am sure other -- the air framing manufacturers are working these areas, too, because we are trying to apply these principles to arrive, and I think Mr. Johnson mentioned a program yesterday called the Avionics Integrity Program which was an attempt to do what we are doing in the structures world in the electronics world. So, there are these initiatives.

CHAIRMAN HALL: Well, I do have a general concern, and I am not being, I hope -- I just -- of how the information is transferred, and I have the opportunity to meet with Administrator Garvey next week, and I am going to ask her to look into being sure that safety information that we get in the military and in commercial that there is some bridges here of transfer.

Now, you said you have been to the -- you work very closely with the folks at Atlantic City and you have been there. I just don't know whether there is any type –– maybe there is no need for a formal process there, but a Boeing aircraft equivalent 747 -- and I understand that the type of operation is different, but there may be some things, you know, that are learned that can be useful.

WITNESS SLENSKI: Well, Mr. Chairman, I think, as I had mentioned previously, many of us sit on committees together now as the military is adopting more of the commercial standards. We sit in committees together.

I know in the wiring installation and materials committees, Boeing has represented all the military services. The FAA even participates in those meetings and –– so, we do have these technical conferences. It is not just myself obviously. Many Air Force, all military personnel in the various disciplines participate in these various industry associations and trade groups where we have that exchange of information.

SO, it seems to be working fairly well, and it is probably improving because we are obviously buying more commercial hardware off the shelf.

CHAIRMAN HALL: Dr. Dunn, you had a comment?

WITNESS DUNN: Yes, I would like to add a little bit to what he said. I think the system could be improved. I will say this. Perhaps some of the things that we are doing in trying to address the White House Commission on Safety and Security is to work more closely with DOD and NASA in order to make sure there is -- the research that they have done, this sort of technology they have developed, as far as it relates to wiring and also their experience base, that those items are factored into our response that we expect to have in June.

In addition, I would like to add that just this year we started the first joint DOD, NASA and FAA aging -- Aging Aircraft Conferences, and these are an ongoing event. There will be another one next year.

In fact, there is -- I got a request at my desk to provide a paper for that conference next year. So, there is - there is that going on, as well as Mr. -- as George mentioned, there is also the aspect of the committees that we all are participants on.

CHAIRMAN HALL: Thank you, Dr. Dunn. Will you continue, please, Dr. Ellingstad?

DR. ELLINGSTAD: I have no further questions, Mr. Chairman.

CHAIRMAN HALL: Okay. Dr. Loeb?

DR. LOEB: I just have a couple of quick questions for Mr. Craycraft to try and take advantage of your forty-one years of experience.

Were you here yesterday, sir?

WITNESS CRAYCRAFT: Yes, sir.

DR. LOEB: You know, in the maintenance report, Exhibit n(a), is a number of write-ups on the reading lights and continuing lighting problems, and then we had the discussion of the problem with the fuel pump volumetric -- help me with this -- overflow shut-off valve.

Then the problem, the situation with the crazy -- 1 call it a fuel indicator. I think that was the word of the crew -- or, fuel flow indicator. Your forty-one years of experience is -- what would you do as an Investigator to look into that matter to be sure that had nothing to do with this tragedy?

WITNESS CRAYCRAFT: Well, first, sir, analyze what each of the items is that it is talking about. I will pick on reading lights for just a moment. They are -- well, one of the reports I noticed in here was just the fact that there was an awful lot of reading light lamps that were burned out. So, obviously that would have no affect on the thing.

Now, there was some comments on overhead lights, and I believe the remark on the overhead lights, they were on the left hand side of the aircraft. So, there, again, I could discount them as being involved because the one particular wire that was referred to in the report, and I don't –– it gave a specific wire number.

I think that is a very short wire, and it only could have been routed in a very short distance to where it could be in proximity to the fuel flow indicator wire, as well as the valve shut–off wiring.

In terms of fuel flow, we have two indicators, one on the flight engineer's panel and one on the Captain's panel. There is no -- I have not read the CVR transcript, so I don't know whether they are making reference to both indicators, or not.

But, the same signal is driving both indicators, so if only the one on the front panel is acting up, then obviously it is not a signal that is coming from the E&E compartment. It is somewhere between the FE's panel and the forward panel. So, there is a lot of analysis opportunity available in looking at those circuits.

CHAIRMAN HALL: Well, the thing that struck me on the lighting, and I have been on a 747 a number of times and I know there is lots of those lights, is just this frequency of over a hundred write-ups. Is that something that you would consider unusual, or is that fairly normal? I know there is a large number of lights on the plane.

WITNESS CRAYCRAFT: Well, I think our aircraft configuration is something like 34 and 404 passengers, so there is obviously a reading light for every seat. So, you have quite a number of opportunities there for reading light lamps to be inoperative .

But, likewise, the multiplex system on the 747 can play tricks on you sometimes of turning lights on when you don’t want them and that sort of thing, and that is strictly associated with difficulties within the multiplex system.

CHAIRMAN HALL: Anyplace else we ought to be looking, sir?

WITNESS CRAYCRAFT: I have been working very diligently with Mr. Swaim and helping him in every opportunity I can to look at these items.

CHAIRMAN HALL: Well, we appreciate your cooperation. Just one last little item. Are you familiar with the plane that we called, I guess, the derelict airplane in 93105?

WITNESS CRAYCRAFT: I am familiar with that airplane, yes.

CHAIRMAN HALL: Do you know why it was removed from service?

WITNESS CRAYCRAFT: I believe it was an economical decision that it was requiring some of these major structural modifications and it wasn't within our operational plan, it wasn't economically feasible to go ahead and accomplish all those man hours of work on that aircraft.

CHAIRMAN HALL: Okay. Any other questions from the Board or the Technical Panel before I go to the Panel?

MR. SWAIM: We have had a question about polyex airplane used in -- I am sorry -- polyex wire used in Naval aircraft in the systems Exhibit 9(c), pages 54 to 58.

There are three letters from the Department of the Navy, two of them to the Honorable James C. Greenwood, House of Representatives, one to the National Electronic Manufacturers' Association spanning 1982 to just three and a half months ago, 1980 -- 1997, and they do show that some Naval aircraft, especially F-14's have polyex wiring.

There were some difficulties which are

described in the letters, and for the most part they were re-wired. So, I hope that answers that question, or at least where to go find the answer for that question.

CHAIRMAN HALL: Okay, anything else?

(No response.)

If not -- no?

MALE VOICE: No, sir.

CHAIRMAN HALL: No? Very well. Well, I would like to do with this panel what I have done with the others, and I don't know whether we will see any of you all tomorrow, or later. Mr. Thomas will still be appearing.

But, I would like to just go down the table, and if there is anything that -- Mr. Vannoy, anything else that you think should be contributed, or else the Board should be doing in this investigation, or anything that needs to be clarified, I would like to give you the opportunity to do that, sir.

WITNESS VANNOY: Thank you, Mr. Chairman. I would first like to thank across the room here the members of the NTSB Technical Panel for their participation today and for all their conduct leading up to this hearing over the last couple of weeks. I appreciate that.

I haven't had quite as much experience as some of the members here on the panel, but I have been in the business for quite a while, and during that time I have had opportunity to participate in many identification through the resolution of the problems.

In that activity my confidence has been continually reinforced, not only at Boeing but by the industry in our commitment to safety. As we have discussed today, the older 747's require more maintenance .

We know that they are a little less reliable from the dispatch standpoint, but we contend that these airplanes are not less safe, and you have our commitment to continued airworthiness activities in every respect on these airplanes. Thank you.

CHAIRMAN HALL: Thank you, Mr. Vannoy. Mr. Thomas?

WITNESS THOMAS: A small comment in your looking for sharing of information. Although we have been prime in trying to understand -- from the aircraft manufacturing side of the house we have been prime in trying to help understand this airplane.

We have reached out to the other airplane manufacturers across the world and asked them to help us . Even at this time last year when we realized identifying the cause was going to be a long effort we started dialogue with Air Bus.

Even though we are on the competitive side of the world where we are forever arguing, as far as safety is concerned we have met with Air Bus, we have met with McDonnell, we have met with Lockheed, and we spent a lot of time going through an awful lot of detail on how we design our airplanes and sharing that information.

I think it is appropriate to recognize that the industry has really come together to try and understand this one.

CHAIRMAN HALL: Well, thank you very much, Mr. Thomas. Mr. Taylor, I must tell you I am impressed to meet anyone with thirty-seven years of experience as a wire expert, and I appreciate your contributions here today in helping make this understandable for the Chairman and for those who are observing.

MR. TAYLOR: Thank you. One of the things that I have noticed about working at Boeing and with other aircraft manufacturers is a continued commitment to safety and their integrity in that regard.

I can assure you that when this hearing is over our commitment to safety will continue as actively and as continuously as it has in the past. When I leave here -- tomorrow, I hope -- when I leave here I will go back and I will continue to do the best I can with my co–workers to make sure that the wire that we have is the best wire, that the condition of the wire on the airplanes that we service we know about, and when we see something that needs action we will take appropriate action, and we will work with other people within the industry to make sure they know what we know and that we know what they know.

CHAIRMAN HALL: Thank you very much, Mr. Taylor. Mr Craycraft, you have done an excellent job of representing Trans World Airlines, Inc. Your comments, please?

WITNESS TAYLOR: I would just like to add for the record I don't know as it had ever been drawn out before, but we have Boeing field service representatives on site at TWA that provides a free flow of information between TWA and Boeing and other air carriers, other manufacturers also, so that it isn't a difficult situation for us to relay any difficulty we have with the aircraft.

Certainly I want to express an opinion that it is our number one objective in the Maintenance Department to supply a safe, reliable aircraft for our flight crews to carry the passengers.

CHAIRMAN HALL: Well, thank you very much, Mr. Craycraft. Mr. Slenski?

WITNESS SLENSKI: Mr. Chairman, I will take an opportunity here to answer one of the questions from yesterday. We had an issue about bonding inside of fuel tanks. We do have active programs, depending on the type of aircraft, to phase inspection on the actual bonding connections. It just depends on the type of aircraft.

CHAIRMAN HALL: SO, the three inches we were talking about --

WITNESS SLENSKI: My understanding is we have gone more to a performance requirement on that where we are now actually specifying an energy level and a voltage level.

CHAIRMAN HALL: Well, you might share that information with the FAA, if they don't all ready have it.

WITNESS SLENSKI: I think as far as the fuels question, I think in the next panel there might be an opportunity to answer that question, I think, as far as – the question was, why did we change from JP–4 to JP-8 . I think that will be answered there.

The other issue I just wanted to point out, too, that I have shown some failures. I don't want to give the impression that we have a wiring problem in the Air Force.

Many of those photos I had shown were over a fifteen year period, and we are aggressive in trying to understand why we had a failure, and fix the problems, and I don't really see that we have a major problem with wiring. It is an issue and it is a concern, and I think, as we have mentioned here, aging electronics is a concern that we need to look at more carefully as avionics becomes more complex.

CHAIRMAN HALL: Well, let me state again for the record that on each -- the 747 has an excellent safety record. I think this was the first accident for Trans World Airlines in a long period of time, and the commitment that we and the cooperation we have received in this investigation, generally speaking, from all the parties has been outstanding and I -- the Chairman certainly has no question over the commitment of the individuals of the organizations involved in this investigation.

Because so much attention and publicity has been given to this investigation, I want the American people to know all of the things that are being done. I hope that it in no way reflects -- as we go through all of the possibilities, all the things that we found in the investigation, it is important for me to point out that we do not have an ignition source in the center tank that we have been able to identify as a probably cause of this accident.

That work will continue, but this is part of the investigation process, and I appreciate your comments very much because I want to be sure the record is clear on each and every opportunity in that regard.

Mr. Crow?

WITNESS CROW: Yes, sir. Thank you, Mr. Chairman. I think in closing I would like just to reiterate that the FAA Flight Standards Service continues to provide professional leadership and surveillance of the air carriers that are currently certificated in operating not only in the U.S., but worldwide.

We continue to pledge to the American public that we will continue to try to do the right thing and to serve the public trust at every opportunity, which includes those revisions and those things that need to be done to insure the highest degree of safety. Thank you.

CHAIRMAN HALL: Thank you. Dr. Dunn?

WITNESS DUNN: Yes, as Bill said, I would like to reiterate the fact that we are -- while we have a system in place that we think adequately addresses continuing airworthiness and aging systems, we are always looking to improve that process.

We don’t have all the answers, and I think a lot of the issues that were addressed here at this Systems Panel are important for our continuing review of our processes, and of course we will be using the information we have gained here in our investigations over the next year. Thank you.

CHAIRMAN HALL: Thank you, Dr. Dunn.

As you may know, the Chairman was honored to have been appointed and serve on the White House Commission on Aviation Security and Safety, and I was in that meeting during a number of discussions where General Lowe, who is a member of that commission, a distinguished Air Force General and I believe Air Combat Commander, was one who was very strong in raising the issue of us looking at aging systems. This was because of his personal experience in going out and looking at a lot of the Air Force fleet.

I don’t know, obviously, but I am glad to see the FAA is looking at that. We will look forward to your report in June in that regard, and I understand you have got that work in progress and that will be coming to us.

Very well. Do we want to start the next panel today? What is the preference, Mr. Dickinson? Do the parties have any preference? Do we want to try and get into the Ignition Sources today and take about an hour or two and then finish it up in the morning?

(No response.)

Well, let's do this then. Let's just say that what we are going to do is we are going to start the Ignition Sources Panel -- now, Ignition what? I am sorry, the Flammability Reduction Panel at 4:00, and then we will go for two hours, and we will recess at 6:00 p.m. and reconvene in the morning at 9:00 to complete the work in that panel.

I hope that since this is such an important panel that none of our distinguished panel participants, or staff, or others feel compressed by the fact that we have been sitting here for four days under these attractive lights that you are going to not get all the information that we need to get out on the record.

I thank everybody, again, with this panel, and we stand in recess until 4:00 p.m. Off the record.

(Whereupon, a brief recess was taken.)

CHAIRMAN HALL: On the record. I would ask the observers in the hall to please take their seats.

We are going to reconvene this National Transportation Safety Board public hearing that is being held in conjunction with -- in connection with the investigation of the aircraft accident TWA Flight 800 that occurred on July 17th, 1996.

Mr. Dickinson, would you please introduce the next panel, which I believe is the panel on Flammability Remediation?

MR. HAUETER: Mr. Chairman, before the panel starts, I would like to correct the record on the Philippines Airlines.

CHAIRMAN HALL: Oh, very well. We have information. Go ahead.

MR. HAUETER: Yes, the airplane was approximately seven months old at the time of the explosion. It had accumulated 1,358 hours and 1,778 cycles, or take-offs and landings. So, I wanted to correct the record.

CHAIRMAN HALL: It was how old? I am sorry.

MR. HAUETER: Approximately seven months.

CHAIRMAN HALL: Seven months old. Very well.

MR. HAUETER: Thank you, sir.

CHAIRMAN HALL: That is good to have that on the record.

WITNESS DUNN: Would the Remediation Panel please stand, please? Actually, it is the Flammability Reduction Panel. Please raise your right hand.

(Witnesses comply.)

Whereupon,

MR. TOM McSWEENEY, MR. HARDY TYSON, DR. ROBERT BALL, MR. RALPH LAUZZE, MR. IVOR THOMAS, CAPTAIN STEVE GREEN

were called as witnesses by and on behalf of the NTSB, and, after having been first duly sworn, were examined and testified on their oath as follows.

MR. DICKINSON: Thank you. Please be seated. This Reduction Panel consists of Mr. Tom McSweeney, Hardy Tyson, Dr. Robert Ball, Ralph Lauzze, Ivor Thomas and Captain Steve Green. They will be questioned -- initially presented with a presentation by Mr. George Anderson and questioned by Bob Swaim and Dr. Dan Bower.

Mr. George Anderson is an NTSB Aerospace Engineer with Aircraft Accident Investigations, and he had two years with the Safety Board. His prior experience in private industry and the Air Force is in mechanical test engineering, aircraft design and overhaul, aircraft performance, human factors, a development engineer for the GAU-830 MM Canon Flight Test Transport, an instructor pilot and a flight examiner.

He has a B.S. in Physics and Electrical

Engineering from the U.S. Air Force Academy, an M.S. in Aeromechanical Engineering from the Air Force Institute of Technology, Engineering Management at Naval Post Graduate School and a U.S. Air Force Aircraft Accident Investigation School at Southern -- the University of Southern California.

Mr. Tom McSweeney, please raise your hand, please.

(Witness complies.)

He is the Director of Aircraft Certification Service for the FAA. He has been with the FAA for twenty-three years, previously served as the Deputy Director of Aircraft Certification Service and has held managerial positions at the FAA in several areas, including the Office of Airworthiness and the Office of Aviation Standards.

He has a Bachelor's degree in Aeronautical Engineering from Northrup U, and a Master's degree in Aeronautical Engineering from California Institute of Technology.

Mr. Hardy Tyson, please identify yourself.

(Witness complies.)

Thank you. A Mechanical Engineer, Naval Air Warfare Center in China Lake, California. He has been at China Lake for fourteen years, and his area of expertise is in the Aircraft Combat Survivability focused in the area of fuel system protection for the Navy and Marine Corp. front line fighter and attack aircraft.

This entails ballistic testing of aircraft and their components with threats likely to be encountered in combat for the purpose of determining their design vulnerabilities and identifying protection requirements .

He is actively involved in research and development for vulnerability reduction concepts, and currently the Navy’s lead live fire test engineer for the F-18 program. He has a Bachelor’s in Mechanical Engineering.

Dr. Robert Ball?

(Witness raises his hand.)

Thank you. Distinguished Professor, Department of Aeronautics and Aeronautics, the Naval Post Graduate School in Monterey, California. Aeronautics and Astronomic.

He is thirty years at the Naval Post Graduate School, and in 1976 he began development of an educational program in Aircraft Combat Survivability. He has conducted courses for NATO and the governments of Canada and Greece.

In 1989 he established an AIAA Technical Committee on Survivability. He has a Bachelor's in Civil Engineering, a Master's degree in Civil Engineering and a Doctorate in Structural Mechanics.

Dr. Ralph Lauzze, please -- I am sorry about pronouncing your name there, but he is the Director of Live Fire Test and Evaluation at the Air Force Research Laboratory.

CHAIRMAN HALL: How is that pronounced, sir?

WITNESS LAUZZE: It is not doctor, but it is Lauzze.

MR. DICKINSON: I am sorry.

WITNESS LAUZZE: That's all right.

CHAIRMAN HALL: That's okay, we have had enough doctors here.

WITNESS LAUZZE: One out of three isn't bad.

(Laughter.)

MR. DICKINSON: He directs testing and evaluation for the Air Force Aircraft and Development including the C–17, B–1, F–22 and C–130. Joint Test Director of the OSD sponsored Live Fire -- Joint Live Fire Program. He oversees the vulnerability live fire evaluations of current front line fielded aircraft.

He is the current Chairman and Air Force principal member to the Tri-Service Joint Technical

Coordinating Group on Aircraft Survivability. He has a B.S. and an M.S. in Mechanical Engineering.

Mr. Ivor Thomas; he is on our fourth panel today and this week, so I won't go over his qualifications . They are on our NTSB web site.

Captain Steve Green, who is an active member of the TWA investigation representing ALPA. He is a pilot flying for TWA, he has been with TWA for nine years and he is currently flying the 767. He is currently the team leader for ALPA's In Flight Icing Certification Project. He also has a B.S. in Aviation.

Mr. George Anderson, I will --

CHAIRMAN HALL: Before Mr. Anderson begins I would like to make note that among this panel are members of the Department of Defense who have contributed timely and highly professional support in many areas of this investigation.

Today we have asked the Department of Defense to assist us by providing expert witnesses for this panel. These witnesses were selected to present an overview of some of the methodology used by the military services to design airplanes that can survive in hostile environments. Over the years these designs have saved the lives of military men and women in both combat and peace time incidents.

I think we will come to understand that the concept of hostile environment includes not only intentional acts of violence using weaponry, but also the extreme operating conditions that are imposed on airlines by the myriad forces of nature.

In spite of the advance technology and sizeable resources that we enjoy in our country, we have yet to design an airplane that can survive all of nature's extremes. In the case of fuel tank hazards, we strive for progress and improvement while recognizing that no system can eliminate all risk.

So, we are going to be looking now -- turning to, you know, what can be done, and I am really looking forward to hearing from this panel. So, please proceed.

Mr. Anderson, it should be noted that you have a long and distinguished career with the Air Force, and have been with the Safety Board in two years. So, I hope there is no conflict of interest in your questioning these folks from the Air Force. Is that all right? You will be sure to give them a hard time, won't you?

MR. ANDERSON: I am sure we will be able to do that. Thank you, sir.

Chairman Hall and Members of the Board of

Inquiry, the subject of this panel is Fuel Tank Flammability Reduction. These witnesses will give us an overview of what measures are currently being taken and what measures could be taken to reduce fuel tank flammability.

Our investigation has examined a number of possible methods for reducing or eliminating fuel tank flammability, including inerting, fuel tank heating and cooling, ullage dilution and aircraft design changes. We have also reviewed some technologies currently used by the military.

We will discuss with these panel members the benefits and other possible ramifications of implementing various methods for either reducing or eliminating fuel flammability in civilian, commercial aircraft. We will also discuss any efforts that are currently underway to achieve this goal.

Good afternoon, Dr. Ball.

WITNESS BALL: Good afternoon, Mr. Anderson.

MR. ANDERSON: We are starting off with you, and I would like you to describe for us, if you would, the aircraft combat survivability discipline that you so ably teach at the Naval Post Graduate School.

WITNESS BALL: Mr. Anderson, I would like to thank you for the opportunity to do this. We are a new discipline. Let me start off by examining how an aircraft can survive in combat.

There are basically two ways. One, if the aircraft can avoid being detected, tracked, engaged and eventually hit by a weapon it will survive. If that is not possible, if an aircraft does get hit, it will survive if it withstands the hit. So, we survive by not getting hit, or if we get hit we withstand that hit.

May I have the first slide, please?

(Slide shown.)

The inability of the aircraft to with -- to avoid being hit, or the likelihood it is hit, we call aircraft susceptibility. The more susceptible an aircraft is, the more likely it is going to be hit in combat. The inability of the aircraft to withstand that hit, or the more likely it is killed given that it is hit, we call aircraft vulnerability.

Aircraft susceptibility and vulnerability are bad attributes of aircraft. We like to design them out of the aircraft. We try to reduce them as much as possible.

If we look at the survivability equation that I have listed at the bottom of the slide there (indicating), survivability -- that is, the likelihood you will survive a mission or an engagement with a weapon – survivability is one minus the product of your susceptibility times your vulnerability.

This is a very powerful equation. It can be used in all parts of life; driving automobiles, crossing the street, whatever. You don’t want to get hit, but if you get hit you don’t want to die. If yOU can reduce that product to susceptibility and vulnerability, you can increase your survivability.

You asked for what survivability is about. That is what we are about. We are a new discipline, a formal discipline in which we have an organized process, part of the systems engineering process, for examining an aircraft design to reduce its susceptibility and to reduce its vulnerability.

Now, how do we do this? Well, if you look at the susceptibility part, we can reduce susceptibility with stealth. We design aircraft to be difficult to detect by the enemy radar sensors and the infrared sensors visually and orally.

We can carry on board electronic counter measures which deceive enemy weapons. We select effective tactics, like attacking at night. We use long range precision guided weapons to increase our survivability by decreasing our likelihood of being hit.

When we look at the vulnerability side, we want to withstand the hit. We don't want fuel tank explosions . We are concerned far more than a .2 millijewel of energy. We are concerned with high explosive rounds going off inside our fuel tank. It is a big problem to us.

We have got to design that aircraft to be rugged and to take a hit and continue to fly. We do that by designing in protection for the fuel system, the flight control system, the crew systems and all the other systems on the aircraft that are providing essential functions that we need to continue to fly. That is us.

MR. ANDERSON: Excuse me. Dr. Ball, has this discipline evolved over time? Could you describe basically how it started and where it is today, roughly?

WITNESS BALL: Yes, as I mentioned earlier, we are a relatively new design discipline. Aircraft have been designed to survive in combat on a -- I would say a haphazard basis, depending upon the emergency. World War I, World War II, you are all familiar with the B-17 aircraft. Ten people on board, eight people were firing guns.

That was susceptibility reduction, trying to destroy the enemy fighters before they could hit the B-17, although the B-17 was designed to be rugged and take hits and fly with holes in it. That was vulnerability reduction.

It has been around, but starting in Southeast Asia the United States went into that war flying aircraft that were developed after the Second World War when the jet engine came along and nuclear warfare was threatened, and aircraft were not specifically designed to fight in the environment we found ourselves in in Southeast Asia in the 1960's.

As a result of having to use aircraft not designed to survive in that environment, the United States lost over 5,000 fixed wing and rotary wing aircraft in that roughly ten year period.

As a result of this large number of aircraft killed, the individual services established survivability organizations within their services, offices that dealt with susceptibility and vulnerability.

In 1971 the services together established the Joint Technical Coordinating Group for Aircraft Survivability, more fondly known as the JTCG/AS, another acronym for you. It is a great organization that has been very effective in establishing survivability as a design discipline. That was one of their goals, establish survivability as a design discipline.

Now, as was mentioned, I am an educator. I was educated in structural mechanics. In the 70's I was asked to work on a problem called hydrodynamic dram in fuel tanks. Hydrodynamic dram is a problem in which a fuel tank can be ripped apart as a bullet or fragment propagates through the fuel in the tank. So, fuel tanks are vulnerable not only to explosions, but they are vulnerable to hydrodynamic dram.

When I learned about JTCG/AS and their goal to establish survivability as a design discipline, I thought to myself, every discipline has educated scientists and engineers in that discipline. People are taught how to do something, how to design a -- I was taught how to design a structure.

SO, I felt that the discipline needed an educational program. So, the Joint Technical Coordinating Group sponsored me to develop an educational program at the Post Graduate School, and in 1977 we developed our first graduate level course in survivability, and I believe it was the first course that was ever developed. We also developed a one week short course. We have had over 3,600 people take one or both of those courses.

In 1985 the AIWA published the Survivability Text Book under sponsorship of JTCG/AS and my authorship. A little plug here, if you will.

(Next slide shown.)

Thank you. It was left out of my bio, so I thought I better slip this in. By the way, I receive no royalties for this. It is a -- it is a best seller. “Fundamentals of Aircraft Combat Survival, the Analysis of Design, ” and I might add it is being translated as we speak into Chinese.

CHAIRMAN HALL: If somebody was interested in getting a copy of that book where could they get it, Dr. Ball, since you mentioned it?

WITNESS BALL: AI -- well, actually, Mr. Hall, I will give you a personal copy. But, AIAA. I will sign it, too. AIAA .

Another major event was in 1987. Congress felt that the military services were perhaps not adequately testing for the vulnerability of their systems, and they wrote the Live Fire Test Law.

This test law requires that all covered weapons systems, platforms and weapons, be tested to determine, in the case of the platform, their vulnerability by firing weapons likely to be encountered in combat at fully configured full scale platforms, such as a full scale aircraft, up and running and carrying ordinance. If that testing turns out to be unreasonably expensive and impractical, a waiver may be granted with the submission of an acceptable alternate test program.

As a result of all of this increased intention on survivability, the aircraft that were developed through the 70's and 80's were far more survivable than those that we fought in with in Southeast Asia.

When we entered into Desert Storm, we only lost 38 aircraft out of 100,000 Sortis. That is a loss rate significantly less than we had had in Southeast Asia, significantly less. Our aircraft were designed to survive, and combat data proved that they did.

We are now to the point where basically -- and military aircraft today is not designed without a major consideration of its survivability. If yOU look at the Joint Strike Fighter, the most recent program in the tactical air world in the Department of Defense, the Joint Strike Fighter, there are four what they call pillars of which this aircraft is built upon; affordability, lethality, supportability and survivability.

SO, and since we have come a long way –– and I think that it has been beneficial to the United States that we -- we win wars with these aircraft.

MR. ANDERSON: Thank you, Dr. Ball. How does the discipline, the survivability discipline, evaluate the fuel tank explosion problem? I think it is useful at this time to –– because we have the background in the academic discipline to focus on that problem and perhaps go into it to some depth.

CHAIRMAN HALL: I wanted to mention here, Mr. Anderson, so that –– Dr. Ball I am sure is aware that the Chairman of the Oversight Committee for the NTSB and the Senate is Senator John McCain, who does an outstanding job and was one of the, I guess, 5,000 aircraft that was lost in Vietnam.

I have got several letters from people talking about the phone system that was in place, I guess, or used during that period, which I guess we are going to get into. But, both Senator McCain and Chairman Jim McDuncan, who is –– I grew up with in Knoxville, Tennessee is the head of our House Aviation Subcommittee.

Both of them have, I think, expressed an interest in this area and being sure that we are, you know, exchanging all the knowledge and information. So, again, I appreciate your presence here, and continue.

WITNESS BALL: Thank you. Okay, to your problem, the fuel tank vulnerability problem. It is also our problem. When we have a vulnerability program, as we do on every aircraft, there are three tasks that we have to perform.

The first task is we have to find out what it is on that aircraft that makes that aircraft vulnerable, and we call those the critical components. Critical components are those components whose kill either individually or jointly will lead to kill of the aircraft.

We have tools that we use to determine the critical components. They are the same ones that you and I have heard mentioned at this public hearing earlier, of the failure modes and effects analysis. There is a failure mode; what is the effect on the continued operation of the aircraft.

There is a fault tree analysis that is used. What events must occur in order for a failure to occur. We use those tools to identify these critical components.

If we look at our F-16 cut-away here,

idealized aircraft, I have identified at least three critical components. This is a gross simplification. There are literally thousands of components on this aircraft, of which perhaps many hundreds are contributing to vulnerability. They are providing essential functions to continue to fly.

The three that I have identified basically represent three major systems; the crew system, the fuel system and the propulsion system, the engine. Not only must we identify these critical components, we must identify the ways in which they are killed. That may not be immediately obvious.

If we examine the engine, we typically think of an engine as if it loses thrust the engine is killed, as we would speak. It is not providing the function it was designed to provide. But, that engine could be hit and it could come apart, throwing blades, possibly hit in the fuel tank with fuel leaking onto a hot engine catching fire. We call these kill modes.

If we look at the fuel system which we are interested in here, we have a variety of kill modes that we must treat in addition to the ullage explosion problem.

Having identified the critical components, we then attempt to quantify vulnerability. We attempt to put a number to it so we can compare aircraft, and the number that we use is called the vulnerable area. Each component has a vulnerable area. There is a vulnerable area for the pilot and one for the fuel tank and one for the engine.

But, I have a little equation at the bottom of the slide on how we calculate vulnerable area (indicating). The vulnerable area of a component is equal to the presented area of that component times the probability that component is killed given that it is hit.

Now, a kill here could be a fuel tank explosion. Keep that in mind, the probability a fuel tank will explode given that that fuel tank is hit. It is basically the problem that you have been dealing with here.

We can -- for this particular aircraft in the configuration shown, the aircraft has a total vulnerable area for these three components made up of the sum of the individual vulnerable areas.

Today, vulnerable area is perhaps one of the requirements that is established on the design of the aircraft. The aircraft shall have a vulnerable area no larger than, and that is the process we go through.

If that fuel system is unprotected, I can guaranty you that because it is the largest system on the aircraft and possibly the most vulnerable system that it is our major contributor, it has got to be protected because we will exceed all vulnerability requirements .

Next slide, please.

(Next slide shown.)

That brings us now to the fuel system, and within the fuel tank I am showing you here -- I apologize for the busy slide. I took it out of the text book, and I want to attribute this slide to a Lavelle Mahood (sic) who originally developed it many, many years ago, and it has been used by many of us in the discipline, and we are grateful for him for coming up . It is a great slide.

You are looking at a fuel tank that is inside an aircraft skin. I think you can read where the fuel is. The area above the fuel, of course, we have been referring to as the ullage, that vapor space.

What I am going to do is I am going to follow the two bullets, or fragments over on the left, follow them into the fuel to see what happens. Coming from the left, the lower left, then, we would have an armour piercing incendiary round, or a fragment penetrating the outer skin of the aircraft creating friction sparks. Possibly, if there is an incendiary involved, the incendiary may function, and we have sparks with considerable energy in them.

The projectile enters in through the skin into the fuel tank creating the phenomena that I referred to earlier, the hydrodynamic dram phenomena. Intense pressure loads are put onto that tank, and it can literally rip that tank apart, destroying perhaps some major structure capability.

The fuel can come spewing out of that hole down to the bottom of the aircraft and perhaps come in contact with an ignition source. Perhaps a hot surface, perhaps some other wires have been cut and we have some arcing going. So, there is a possibility of a dry bay fire in the belly of the aircraft.

If we move up to the upper left now (indicating), we have followed that shot coming in. The ullage is idealized there as being stratified into three layers. Close to the fuel it is too rich, at the very top it is too lean, and there in the middle we have got a just right for burning. This is an idealization. In reality, we don't know the conditions in the ullage.

If you went out and measured your temperature -- if that is all we had to do we would be happy. Don't forget, the pilot is probably pulling about five or six G–s trying to avoid this round that is coming up at him. We don't know where the fuel is in that tank. There is vibration, there is sloshing, there is mixing. We don't know the temperature, we don't know his flight profile. We don't know the conditions . We deal with a large number of unknowns. That is how we treat the fuel tank problem.

MR. ANDERSON: Dr. Ball, following on with the illustration and keeping the slide on, please, could you explain in a little more detail what other threats to the fuel tank that might be represented by the bullet, such as uncontained engine failures, which would be very –– is something that is encountered in the commercial aviation world, and even specifically in the Boeing 747.

Also, the issue of -- we have called them sparks here, but other sources of ignition.

WITNESS BALL: Yes, the -- if an engine comes apart, obviously if –– it depends on where the engine is. The parts that come free from the engine can pass through the fuselage and into fuselage tanks, into wings and into wing tanks. Possibly, a very intense bird strike.

The tank that I have shown here is a selfcontained tank. Many of our tanks are what we call wet wing, or integral tanks in which the tank wall is basically the same as the outer skin of the aircraft, and any penetration of that skin will penetrate into the fuel.

SO, any physical body, large or small, that has enough energy to penetrate into the skin can either create the hydraulic dram phenomena if it goes into the fuel, or if it has heat energy of some form it can actually create an explosion, such as a, you know, a hot turbine fan blade breaking off and going through.

MR. ANDERSON: Just one further note of clarification here. You mentioned the sparks emanating from the projectiles entering the tank. Would it be fair to say that that is equivalent to creating a spark Of, you know, electrical origin in terms of that it could be quantified the same way, perhaps?

WITNESS BALL: I have heard of friction sparks being related to the type of thing you see, somebody using a grinding wheel. But, what we see are friction sparks of considerably more power, more energy.

These are sparks created by fragments, maybe five hundredths of a pound, that hit the aircraft at 5,000 or 6,000 feet per second. This is -- there is a lot of energy there.

If you ever see this happen, if you have ever seen a warhead detonate below an aircraft, the entire frame will be obscured by the light emitted by these liberated fragments or friction sparks, if you will, as they glow.

MR. ANDERSON: Thank you. Moving ahead, Dr. Ball, are there any other military disciplines involved in the prevention of fuel tank explosions?

WITNESS BALL: Yes. Yes, there is. There is another one. I am getting a little out of my area now, so I am going to be speaking for a discipline I am really not a part of, but we share some common problems. It is the systems safety discipline.

If I may have the next slide, please.

(Next slide shown.)

If you think about an aircraft operating in a number of environments, I have identified on this slide three environments and, Mr. Hall, I would like to thank you for your lead-in because it was the perfect set-up for what I am going to talk about.

If we are dealing in a man-made hostile environment, there is an enemy out there who is attempting to kill our aircraft, and we typically think of it as an air defense, but you may think of it as a terrorist. In that environment, you are dealing with the combat survivability world.

If you look at the natural hostile environment which Mr. Hall mentioned earlier where we have lightning strikes, crashes, mid-air collisions, severe turbulence, that kind of thing, where the aircraft is stressed in many ways at much higher levels than normal.

There we have two communities coming together. We have a survivability community, which is larger than the combat survivability community, and we have the systems safety world.

If we go to the third world that we are most used to, the normal operating environment, that is the world of systems safety and they look at internal system failures.

There is a spark inside the tank due to some internal system failure, and they also look at things like operator errors, and that is their world. We overlap in this fuel explosion problem. We have many other areas that we overlap.

Okay, next slide, please.

(Next slide shown.)

The systems safety world has different terminology. You have heard me talk about susceptibility and vulnerability and critical components. The systems safety world deals in what they call hazards and mishaps.

A hazard would be a fuel tank ullage with an explosive vapor and an ignition source. That is a hazard that leads to an explosion. That that explosion causes damage to the aircraft, perhaps destroying the aircraft, that is a mishap; not an accident, but a mishap in the systems safety terminology. So, hazards lead to explosions, and mishaps are related to the damage caused by the explosion.

The systems safety world attempts to evaluate hazards using hazard analysis. They identify hazards, just like we identify critical components and how those components are killed. We use the same tools, the FMEA's and the fault tree analysis.

They rank their hazards in a different way than we do. They use what is called the hazard risk assessment matrix.

May I have the next slide, please.

(Next slide shown.)

The systems safety world has a military standard, Mil 882-c, and in this mil standard they describe the hazard risk assessment matrix, and it is based upon two factors, if you will. What is the severity of the outcome of the mishap? Is it catastrophic, if the aircraft breaks apart; is it critical, the aircraft is damaged; is it marginal; or, is it negligible. That is one of the parameters.

The other factor or parameter is, how often will that hazard occur? Is it frequent, probable, occasional, remote, improbable, or impossible? Now, these are all words in the English language, and they probably mean different things to different people, and I am sure the people that put this together realized that, and there is some latitude as what one might mean by "improbable."

You have to look at whether you are dealing with a single aircraft in terms of improbability, or whether you are dealing with a fleet of 2,000 aircraft when you are talking about improbability. So, these numbers have some lat -- or, these definitions have some latitude, and the mil standard gives some explanation of what they are thinking about for these particular numbers.

The individual severity categories are numbered one, two, three, four. The ranking given to them is just the opposite; four, three, two, one. The probability, A through F, is given in numerical measures 6 through 1, and the hazard/risk -- or, the hazard -- risk/hazard, hazard/risk index is the product of the severity and the probability.

I have indicated there, there is basically three categories. I am not sure it shows up on the figure . Those that are in the dark red, if you will (indicating), are numbers or products between 12 and 24. Those are unacceptable.

If a design has a hazard with an index of 15, that is unacceptable and must be eliminated. Controlled is the word they use, and they have various ways of controlling it.

If it is 8 and 9 -- or, 8, 9, or 10, then it is acceptable with review. In other words, the Program Manager must have people look at this and decide. He or she must make the decision, “yes, that is a hazard and it can happen, but I am willing to accept it for my aircraft. “

The others, the A-6 through 1 is acceptable without review. So, all hazards, then, are ranked according to that risk – that hazard/risk assessment matrix.

MR. ANDERSON: Dr. Ball, the -- could we have the slide back for another moment, please, slide nine?

(Slide shown.)

Could you talk a little bit about the -- you talked a little bit about rating the problem as far as probability of occurrence. What type of inputs would typically go into establishing those categories?

Would it be based on testing? –– and, if so, what kind of tests would be done? Would they be full scale tests with a complete aircraft, or would they be subsystems? Could you comment on that, please?

WITNESS BALL: Mr. Anderson, I beg to put that question off. I don't want to say what the system safety people do, because I don't know.

MR. ANDERSON: Okay, thank you. Now, Mr. Tyson, as a tester at China Lake, would you have some comments on that?

WITNESS TYSON: Again, I am from the aircraft vulnerability community, and we do interface with the Navy safety people when we are dealing with a system that we have a crossover like dry bay fire protection -- that is, the areas outside the fuel tank that might catch on fire -- and when we have a fire protection system within the tank. But, I honestly -- that is out of my field.

MR. ANDERSON: So, you know that these categories exist, but we don't know where they come from in terms of testing versus hazard analysis?

WITNESS TYSON: That is correct.

MR. ANDERSON: Is that a fair statement?

WITNESS TYSON: Yes.

MR. ANDERSON: Yes, okay. Dr. Ball, I think we are -- we appreciate the overview very much of where the military community has come and how it has got to this place.

I think at this time I would like to ask you to get into the actual concepts of preventing fuel tank explosions which this discipline, of course, has produced.

WITNESS BALL: Yes, Mr. Anderson. I hope I don't inundate you with material you have seen for many times throughout this public hearing, but I do need it to lay some foundation, and I have discovered sometimes that repetition can be helpful.

May I have the next slide, please?

(Next slide shown.)

There is a fuel tank. It is any one you want to think of. It is in a wing, it is in a fuselage, it could be carried externally. It is idealized with the level of fuel.

In any ullage we have a mixture of air containing nitrogen and oxygen, and fuel has evaporated into that. It is called the ullage. There is a certain amount of fuel vapor there and there is a certain amount of air there.

Next slide.

(Next slide shown.)

We have assumed a uniform ullage. I have eliminated the stratification and the non-homogeneity here to make it simple. An ignition source appears. In our case it could be an incendiary round, it could be a hot fragment. A number of things could have created it. It could be an explosive warhead. There is an ignition source.

If the ullage surrounding -- the vapor space surrounding that ignition source is combustible, combustion will occur and a flame front, or combustion wage will propagate roughly spherically in this situation, away from that ignition source, and it will move through that ullage as long as combustion can continue.

Behind the flame front is a relatively hot, relatively high pressure gas. If we look at the chemical equation given at the bottom of the slide (indicating) -- I apologize for that -- it is basically a CN/HM, a hydrocarbon fuel, JP-4, JP-5, JP-8 Jet-A, plus oxygen and nitrogen, and that is what is in the ullage, three different species of gas.

If that energy source has sufficient energy, there will be a chemical reaction and the hydrogen will combine with the oxygen to give hot water vapor, the carbon will combine with the oxygen to give hot CO_2, the nitrogen kind of goes along for the ride. There are some other products, and there is heat of combustion. This is an exothermic sustained chemical reaction.

Now, the question is, when will that occur?

Next slide.

(Next slide shown.)

Flammability diagram. This is a diagram in which we attempt to show the region of temperature and altitude for aircraft in which combustion will occur. Now, it is a bit misleading to talk about temperature and altitude, because we are really interested in this fuel vapor and oxygen.

So, you will see I have on the lower axis, going from left to right, temperature, but temperature directly affects fuel vapor. So, as temperature goes up, fuel vapor goes up. If you look at the vertical axis, the altitude axis, it is a little confusing because as you go up in altitude, you go down in oxygen.

It makes it a little bit confusing, but why does that happen? Well, the reason that happens is the aircraft must maintain a certain differential over–pressure within the ullage, and as it climbs to altitude the lower pressure outside the fuel tank gets smaller, and therefore the aircraft fuel ullage is vented and air is released into the atmosphere and the oxygen goes down.

Now, that gets a little bit confused by the fact that there may be oxygen in the fuel, and that oxygen dissolved in the fuel, and that oxygen will then leave the fuel and go back up into the ullage. So, instead of losing oxygen, we gain oxygen. So, it is not a clear situation.

Now, I have indicated on this flammability diagram an aircraft located at -- three aircraft located at the same altitude with three different temperatures, A, B and C. Okay.

Now let’s go to the next slide.

(Next slide shown.)

We ran down to China Lake and Hardy runs some tests for us and he takes the temperature and the oxygen composition at altitude indicated by A, and he says “I don’t get combustion.”

What he really means is that the wave front doesn’t go back, or if there is a little wave –– maybe the over-pressure that is created by the spark is really not very large.

Then he tests B and he says, “Yeah, real nice, I have got about 100 PSI, a nice deflagration.” I know you have heard that word earlier. Then he goes over to C and he says, “No, it didn’t work, no over-pressure generated by that spark.”

So, we have a region A, too lean; a region B, just right, the combustible region; and the region C, too rich. We indicate the debarkation between those as if it were a nice, straight line, a nice line there. Well, it isn’t. It is a fuzzy line. The position of the line depends upon the amount of energy in the spark, or, in our case, incendiary particle.

The more energy, the wider that region will be. The location of the region along the temperature axis is a function of volatility to the fuel. The combustion region could be way off to the left if we have a highly volatile fuel. It could be way off to the right if we have a very low volatility fuel. So, those are the parameters that we have to deal with when we want to protect our system.

Now, the thing slants to the left, and you kind of wonder, well, why is that? Well, that complicates things because you can’t just pick a temperature at sea level and make it work at 30,000 feet. As a matter of fact, about 60,000 feet up there it cuts off entirely. There is not enough oxygen out there at 60,000 or above to support combustion.

The reason it slopes to the left is that as you go up in altitude at the same temperature the fuel vapor remains constant, but the oxygen level goes down and, so, you go from basically being too lean -- okay, you have got too much oxygen, to just the right amount of oxygen, and you become combustible.

Now, every aircraft that flies a flight profile will go through that altitude temperature region, and you can draw lines and watch that thing move through that region. Sometimes it will be an A, sometimes it may be in B, and sometimes it will be in C. Of course the question here has been, how long is it in B?

Next slide.

(Next slide shown.)

We have some names that we give to these portions of this thing. We talk about the flammability limit. It is a little bit difficult when we talk about flammability limits, because we use different ignition sources.

Sometimes we use flame, sometimes we use sparks. In our particular case we could use incendiary rounds, or we could use high explosive warheads. So, the flammability word is perhaps a bit misleading.

We have on the left a lower flammability limit, on the right an upper flammability limit. I showed arrows to indicate that those values are at sea level.

They have values for all altitudes, but I have indicated they are at sea level, and there at the bottom I have taken some typical numbers out of the CRC handbook, and I have given the reference there, the Handbook of Aviation Fuel Properties, just to give us some talking position.

Okay, with that as background, then, what I would like to do is to take a look at that diagram and figure out what we can do now to prevent combustion from happening. We do that by shrinking or moving that flammability region, or that combustion region.

Next slide, please.

(Next slide shown.)

First of all -- okay. Fuel tank explosion prevention; perhaps I should say prevent/suppression because prevention to me would imply that there is no combustion process at all that occurs. Suppression would indicate, perhaps, that there is some combustion going on, but the over-pressure generated is something that the fuel tank can withstand. These techniques work on one or the other of those, prevention or suppression.

First, reduction in the amount of fuel vapor; basically making the ullage too lean. There are a variety of ways of doing that. We can reduce the fuel vapor by reducing the volatility of the fuel, by cooling the fuel, by sweeping the ullage.

Another technique; dilution of the oxygen content, which we typically refer to as inerting. Now we don't have enough oxygen and we are too rich. I mentioned at 60,000 feet there is not enough oxygen above that to support combustion. We have inerted the ullage.

A third technique, of course on an entirely different principle, a break-down of the combustion chain reaction. Combustion is a very complex process. It just doesn't go from the hydrocarbon fuel and oxygen, nitrogen over to hot water vapor and hot carbon dioxide.

There are many intermediate products, and there are certain chemicals that when you introduce into that process will prevent it from going through completion. It is called breaking down the combustion chain reaction.

Another technique is to absorb the heat of combustion. The reason the combustion wave propagates through the ullage is that enough heat is liberated by the process to support the combustion taking place in the unburned region, and the wave moves forward. If you could remove that heat, you could prevent that from happening.

Finally, there is a physical technique; interfering with the combustion mixing. Combustion needs room to move. If you give it a very small space, confine it, it has difficulty generating those hundred PSI over–pressures. That is how we prevent combustion.

MR. ANDERSON: Thank you, Dr. Ball. Moving from the theoretical underpinnings, if you will, of how we go about designing systems, could you describe the specific techniques that have been developed by the Department of Defense to accomplish the goal of fuel tank explosion prevention?

WITNESS BALL: I am just going to prevent some of them. We refer to them typically as passive or active. Passive means it is simply there and we don’t have to worry about it.

The first one we have on the list there is foams, and a safety foam. It is an open-celled reticulated polyurethane, or fibrous filler. There is another one I don’t have on the list called expanded metal foil.

Nitrogen inerting is another technique. You can obtain nitrogen to put into the fuel tank ullages using on board liquid nitrogen, or stored in gas bottles. Or, you can generate the nitrogen as the aircraft flies using a system called on board inert gas generating system, or OBIGS.

Halon 1301 is a chemical that we can -- it is a gas we can put into the ullage, and it breaks down the combustion chain. Unfortunately, the Halon gases are no longer going to be available to us, and I think Hardy and Ralph will address that issue later.

Ullage venting; again, reducing the fuel vapor, or ullage sweeping it is sometimes called. The use of additives. In other words, we can actually take some additives, powder, if you will, and put it into the fuel and it will reduce the volatility of the fuel. It would be less likely to mist, less likely to evaporate, and the use of low volatility fuel itself.

There is an active technique that we have been investigating. Flame front detection using some type of sensor, perhaps an optical sensor to detect the radiation from the front, and then combustion suppression by dispensing some sort of gas into the ullage to suppress the development of the over–pressure. Those are the techniques that have been investigated, and many of them are in use today.

CHAIRMAN HALL: I was wondering if Dr. Ball was aware of the anti–static additive they put in Europe and whether that is done in the military, or whether there is any anti–static additive added to military fuel in this country?

WITNESS BALL: No, I am not. I am just not aware whether there is or there isn't. It doesn't, to my knowledge, have any effect on the suppression or prevention of the explosion. So, I have not looked into that.

MR. ANDERSON: Thank you, Dr. Ball. The various techniques there, another term for de–oxygenating the fuel I believe is scrubbing, is that correct? Is that a usable term?

WITNESS BALL: Well, scrubbing refers to the fact that fuel, as I mentioned earlier, has dissolved oxygen, and if the aircraft is, we will say, sitting on the ground and is re-fueled, there is a lot of oxygen in that fuel.

As it climbs to altitude we want to get rid of the oxygen. If we are going to use an inerting system, we want to get the oxygen out of there, and I mentioned that climbing to altitude is good because you get the air out of the ullage, but you get oxygen bubbling up through the fuel and into the ullage, and you need to get rid of that.

So, what they do is they actually scrub the fuel by passing, perhaps, some of this inerting gas through the fuel, capturing the oxygen and dispensing with it very quickly during the early times of flight.

MR. ANDERSON: Yes, and perhaps the reason for bringing that up as a clarification is that a complete nitrogen based inerting system might consist of two components, and I know we will get into it later, but the terminology has a tendency to get mixed from here on when we are talking about different systems.

But, the scrubbing would be the removal of oxygen from the fuel by bubbling, and then the ullage, which is where the oxygen ends up, is inerted with the nitrogen. Is that a correct characterization of that kind of system?

WITNESS BALL: That is my understanding.

MR. ANDERSON: Thank you. Can you give us examples of techniques used in current U.S. military aircraft, both combat aircraft, for a reference, and transport aircraft that are equivalent in may ways and, in fact, identical in some other ways to commercial aircraft?

WITNESS BALL: Yes, Mr. Anderson.

Next slide, please.

(Next slide shown.)

Okay, I have looked around into the various used military aircraft, and these are the -- these are some of the aircraft of which I can speak about that I have found fuel system protection. I have divided them into fighters -- 1 should say fighter/attack and the transports, the tactical and then the transport world.

If you will notice the -- also on there I have indicted the type of system that is used and the approximate year of program start. In all cases except over on the right, the C-130, the fuel system protection scheme that was used was original, and in the original design of the aircraft.

Over on the C-130 which was, I believe, developed -- it was started in 1950's, foam was not inserted until, I believe, in Southeast Asia. But, all the other aircraft actually had the foam installed at the time -- or, designed to be installed at the time the program started.

so, it gives you some idea of the fact that we have been using foam since the 1960's and, Mr. Hall, I believe you mentioned the foam in the Air Force aircraft. The Air Force used an orange foam at that time in their aircraft.

CHAIRMAN HALL: Senator McCain was a Naval --

WITNESS BALL: Yeah, I was thinking of --

CHAIRMAN HALL: Don't get me in trouble that way.

WITNESS BALL: I know. I was thinking of that and Marty helped me out here.

CHAIRMAN HALL: Did I say Air Force?

WITNESS BALL: I don't remember any Navy aircraft that had foam in Southeast Asia, but Hardy could maybe correct me here.

CHAIRMAN HALL: Well, that's why I wanted to check.

WITNESS BALL: Yeah.

CHAIRMAN HALL: I will pull the letter up here and see if that is correct, or not.

WITNESS BALL: The Air Force did put foam in their aircraft. The Air Force was flying JP-4, the Navy was flying JP-5, much less volatile, and they didn't believe they had the problem the Air Force had.

Going back to my slide with the systems. So, when you see a year on there, that is not from when the aircraft started, but actually when the aircraft started with that protection system.

So, we have the F–15 and the A–10, and for the Air Force with foam. We have the Navy F-18 with foam, and the current version still has foam. The EF coming out has foam. The F-16 has Halon. That is called part–time Halon because it is only used as the aircraft flies into combat, and the F–22 is designed to have OBIGS, that on board inert gas generating system.

Over in the transport world, the C-130 had foam, the C-5 has on board liquid nitrogen, the C-17 has OBIGS and the V-22 is designed to have OBIGS. I believe that is a representative list of military aircraft that we can talk about.

MR. ANDERSON: Thank you, Dr. Ball. I would just like to add several items. As I prepared for this panel, I talked to a number of people in the civilian community who were retired from the military, and I wanted to find out a little more of how some of these things had happened.

One of the areas was, as you mentioned, CO_2 inerting, and I would just like to mention that I was told several anecdotes of testing which is, of course, long buried in the official record of the B-36 in the late 40's and early 50's which installed on a developmental basis the CF-2 system.

I was also told by the same individuals that the system did not prove to be successful because they had difficulties with the CO_2 gas going in solution with the aviation gas, which at that time was 115–145 grade, a very high volatility gas, and it caused cavitation of the fuel pumps.

The other anecdotal use of flammability reduction was a little interesting. During World War II the Russians in their ground attack airplane, the Stormovic, used anecdote exhaust gases vented through a vent system into the tanks and was successful by a lot of accounts in – of suppressing fuel tank explosions, or fires.

The last one I wanted to talk about, the C-5A and C–5B aircraft, which are, of course, operating today and in a very successful manner. The gentleman I talked to was -- who is retired was responsible for procuring that system, and I thought it was useful to note that he said that the system was not delivered with the airplane and not developed with the airplane, but was added later.

The reason he told me that it was added later was because three C–5's had been destroyed on the ground due to fire. In one case it was a re-fueling accident. In another case it was a depot entry into the fuel tank where heaters or something were wrong. I believe the third case was -- may have been in the air, but I am not sure.

But, I thought it was important to mention that the C-5 nitrogen system which is, I believe, a liquid nitrogen system, was put on the airplane for the purpose of preserving the assay.

I would like to move to Mr. Tyson. Good afternoon, Mr. Tyson.

MR. TYSON : Good afternoon.

MR. .ANDERSON: Could you share with us the role that you are currently playing in reducing flight hazards on U.S. Navy aircraft?

WITNESS TYSON: Yes. My colleagues and I at China Lake test Navy and Marine Corp aircraft to identify areas where we can make improvements to their survivability.

Now, we just don't go out and shoot airplanes at random. We use tools, modeling tools, as Dr. Ball has illustrated in his earlier view graphs, to guide us to the areas of the airplane that might need attention.

We also use engineering judgment. Say the modelers haven't captured something that we think might have a vulnerability associated with it. We will test that.

Going back a little bit to the question you referred to me earlier, we have also had the safety community come to us with concerns about certain areas of an airplane and say, “Could you test this, we think there might be a problem.” We have, and successfully installed protection equipment as a result of good engineering judgment by the safety people, also.

We also test aircraft to verify the performance of installed protection systems. In addition to testing aircraft, we are continually involved in R&D to identify new technologies for accomplishing our goals of improving survivability for current and future aircraft.

MR. ANDERSON: The next question I would have for you in that context and in that area is, essentially what tests are you familiar with, or have you participated in that would help us to understand the methodology of testing fuel tank hazard conditions?

WITNESS TYSON: We have accomplished many tests that specifically address fuel tank hazards. Can I have my first slide, please?

(Slide shown.)

This is a series of photographs from a high speed film taken by a professional photographer, Dan Zern (sic), of a test I conducted collecting data to support requirements for an OBIG system for a Navy aircraft. As Dr. Ball mentioned, OBIG stands for on board inert gas generating system.

As you can see from the photograph, our testing in the field is very much in agreement with what was presented by panel six, the Flammability panel on Tuesday.

This particular test is a spark-ignited test. The energy of this spark was nineteen jewels. What we have here is a two-stage free radical branch chain reaction.

The first stage of the reaction is visualized there in the photographs by the propagation of the blue flame you see extending through the volume we had representing the fuel tank. That volume was thirty cubic feet.

What is behind that blue flame is hydrocarbon fragments. As Dr. Ball mentioned in his chemical equation, things don’t normally transition from the hydrocarbon in oxygen immediately to products of combustion, and that is what we are looking at there.

In the bottom center photograph (indicating), what we have is a complete –– a very intense light source derived from the triggering of those hydrocarbon fragments, which are free radicals, to products of combustion.

The pressure that is associated with the first stage is on the order of one or two PSI, and the pressure that is associated with that violent transition to products of combustion is on the order of eight times the initial pressure at ideal conditions.

This test was conducted at a pressure altitude using standard day tables at 14,687 feet. The initial temperature was ninety–five degrees and the fuel was a JP-4 fuel vapor similant.

The JP-4 similant that we used consists of fifteen of the highest volatile constituents of the JP-4 fuel, as sampled in the stockpile across the country at the time the study was done.

This reaction is very well described by Louis and Vonelle (sic) in their classic text, “Combustion, Flames and Explosions of Gases.” I also want to point out while we are on this slide that there is a tremendous difference in a spark-ignited ullage explosion and an ullage explosion initiated by the threats that we are concerned with.

In many cases, the threats we are looking at consist of thirty–five, forty, fifty grams of a high explosive that detonate within the tank, and in that case you don’t see this nice progression of this flame front that -- the fire ball is so big from the detonation of the HI that you see a real rapid transition to the products of combustion and a real rapid rise in the pressure inside the tank.

Now, that is important, particularly if we are trying to suppress the explosion. Dr. Ball made the distinction between prevention and suppression. Prevention is more like an inerting where we have a fire-fighting agent existing in the ullage space before we are hit.

If we are going to suppress an explosion, we have a fire-fighting agent contained in one or many containers within the ullage that then, when we detect the event starting to occur, we then release our fire-fighting agent and try to attack that situation before it gets critical to the airplane.

It is a much harder problem to suppress an explosion than it is to inert for an explosion, and we have done both. As you might expect, since it is a more difficult problem, we haven’t been as successful as often in suppressing explosions, but we have tested some systems that show a lot of promise.

We have tested a system called LFE. It stands for linear fire extinguisher. It is a tube that contains a fire–fighting agent, and along the length of the tube is a flexible linear shaped charge, and when we detect an event going on, that flexible linear shaped charge rips the tube open and disburses the fire-fighting agent throughout the ullage.

As I said, in many cases we have been able to affect the over–pressure significantly. There are no current active explosion suppression systems installed on Navy airplanes, however.

Let’s see, can I have my next slide?

(Next slide shown.)

I am going to talk a little bit about the OBIG system now. The defining word for inerting fuel tank ullages was done in 1950 -- or, reported, anyway, in 1955 by Stuart and Starkman who were at Wright Labs, I believe, and their document is entitled “Inerting Conditions for Aircraft Fuel Tanks.”

I am sorry, could we go to the previous slide, the one labelled 18.

(Previous slide shown.)

Yes. You can get a rough idea for the dimensions of these membranes -- they are hairlike -- by the dimensions shown in the upper left. The way they function is there is an air inlet. This is a high pressure air that is coming from some source in the airplane that I will talk about later, and the air contains twenty-one percent oxygen.

As the air is passed through the membrane module the exhaust gas, which is oxygen, CO_2 and water vapor, preferentially permeates the membrane because of the molecular size of those molecules is smaller than the nitrogen. You can see in the output of that cartoon module, the inert gas we are indicating less than nine percent.

In that defining work by Stuart and Starkman, they identified that if you inerted your ullage to less than nine percent oxygen you would not get combustion or an explosion event to occur in the tank, and we have tested many different threats. I believe their threat in their document was a spark.

We have tested many different threats that we are concerned with, and sparks, and we have found that number to be accurate. In fact, for some of the larger threats that we use, we can tolerate oxygen content a little higher than that and still accomplish the same feat.

That number also changes with altitude. It can -- the amount of -- the percent of oxygen you can tolerate changes, goes up with altitude somewhat, and as Dr. Ball indicated in the flammability curves, if you get to about 60,000 feet, there is not enough oxygen existing in the ambient air, anyway, to support combustion.

Okay, can I have the next slide?

(Next slide shown.)

This is a very simplified illustration of the concept of operation for an OBIG system. As indicated in this slide, engine bleed air is taken and put through a conditioning unit to put the air that is going to be put into the air separation module within the limits that the air separation module can tolerate.

It is also filtered, and then there is a pressure regulator so you don't over-pressurize the module. Then you see the module. Then there is flow restrictions, and finally you see in this illustration what we talked about a little bit earlier, that the gas is inserted into the lower part of the tank so we can take advantage of scrubbing the fuel as it makes its way to the ullage, and make the ullage inert.

The Navy has successfully implemented OBIGS on Navy and Marine Corp aircraft. When I say the Navy, it is really a team of government and industry where the Navy develops the requirements based on existing data, or tests to define specific requirements, and then the team designs and produces a system that meets those requirements.

Can I have the next slide, please.

(Next slide shown.)

Next I would like to make a few comments about foam. Foam is a mature technology that we have tested many times, and it works. The mechanism by which it works are listed here. It prevents passage of the flame front.

The wetted foam -- and it is wetted with fuel as a result of being within the fuel tank -- acts as a heat sink, and that is a measurable part of the pressure reduction that we see when we use foam as a protection technique for ullage explosion.

The part of the fuel tank that has foam in it, and they are not necessarily always 100 percent patched, also provides pressure relief volume to keep the pressures in the aircraft below the point at which you would see structural failure.

I have a sample of foam here that I would like to pass over to the Chairman. This is the latest technology foam.

(Sample proffered to the Chairman.)

As I mentioned before, it works very successfully. It does have weight and penalty volumes by spec. I believe the spec requires that it weigh one and a half -- no more than one and a half pounds per cubic foot. The manufacturers of the foam have demonstrated a lighter weight than that.

The spec also requires that it not retain anymore than two and a half percent by volume fuel, and it also –– this spec also requires that the foam not displace anymore than two and a half percent by volume.

CHAIRMAN HALL: Mr. Tyson, I understand the word foam. Reticulated, I don’t. Now, what is that?

WITNESS TYSON: In general, I will try to answer that. In general, the foam -- the material called polyether is bubbled. The reticulation process takes the membranes between the structure you see there away so that it is an open–cell foam, and that is I believe what is referred to as reticulated.

Do you want to help me out there, Ralph?

WITNESS LAUZZE: One of my favorite expressions for that, sir, reticulated means the interstices of foam.

(Laughter.)

It is the holes.

CHAIRMAN HALL: Okay, whatever. Let’s pass this down to the party table, would you please, Tricia, so they can look at them, as well?

(Sample proffered to the Party Participants.)

MR. BIRKY: Mr. Chairman, if I might comment on that, if I could, a little bit? There are generally two types of foam, closed cell foams and open cell foams . Closed -- you have to have open-cell in the tank or you don't have any room for your fuel.

WITNESS TYSON: I would like to thank Jim Marginette (sic) for providing that sample to us. Dr. Ball also mentioned a -- an expanded aluminum foil, and I have a sample of that here, too, that I would like to share with you.

It also does a fine job of suppressing an ullage explosion, and basically what it does is it prevents the flame from passing, passing through the ullage.

(Sample proffered to the Chairman and Party Participants .)

Maybe Ralph Lauzze from the Air Force has some comments he would like to add to what I have --

CHAIRMAN HALL: Are you familiar with a Dr. S.S. Marsden? He is Emeritus at Stanford's Department of Petroleum Engineering, and he sent us an article I will share with you on the steaming potential and the rheology of foam.

WITNESS TYSON: No, sir, I am not familiar with him.

CHAIRMAN HALL: Okay, thank you. Please

proceed.

MR. ANDERSON: Thank you, Mr. Tyson. Before we go over to the Air Force and Mr. Lauzze, I would like to just follow up on a few items here, but the last area we could follow up on first.

Could yOU -- I think we will talk a little more about this, but just repeat the mechanism by which the foam works.

WITNESS TYSON: In the testing I have done, I have been able to notice a difference in the three that I have listed there. It prevents passage of the flame front, the wetted foam acts as a heat sink, and it provides pressure relief volume.

In tests that I have conducted where the foam was not wetted first with fuel, there is a measurable difference in the over-pressure measured in the tank, even though we suppressed the explosion. It is on the order of a few PSI. It is not very large.

Then, of course, the pressure relief volume, I mentioned that there are installations that work that don’t require 100 percent -- the volume of the tank to be 100 percent packed with foam.

I am going to introduce a very confusing term. We call that gross voiding. In other words, part of the tank is voided of foam, and that minimizes the weight and volume penalties associated with foam being installed in a fuel tank.

As might be expected, if you have half of the gasses in a fuel tank reacting in some way to the combustion process, it will generate less pressure than if all of the gasses in a fuel tank are reacting, and in that manner is the last bullet where the part that doesn't react adds volume for that pressure that did react to expand, too.

MR. ANDERSON: Thank you very much. The other area --

CHAIRMAN HALL: Well, help me. Does that foam totally fill the tank, or does it lay at the bottom, or is it -- what does it look like in the tank? If the machinists go in, is it -- where is it?

WITNESS TYSON: In some installations it is fully packed, yes. In -- in the F-18 aircraft the wings are protected with foam and it is not fully packed, and it works fine.

It is constructed in such a manner that the foam is located on the upper portion of the fuel tank and installed in between the ribs and spars, and it is in the volume of the tank where the fuel is burned first so that it gives protection when needed.

CHAIRMAN HALL: Have you ever been in a tank with foam, Mr. Labelle?

MR. LIDDELL: Mr. Chairman, yes, and it is Liddell. It is Liddell.

CHAIRMAN HALL: Liddell, I am sorry.

MR. LIDDELL: But, my experience with the foam is in Air National Guard F-15’s and F-4’s. It gave us a maintenance penalty and we wound up removing it.

CHAIRMAN HALL: Okay, thank you. Proceed, Mr. Tyson.

WITNESS TYSON: I am done.

MR. ANDERSON: Yes, I wanted to follow up on your very interesting discussion of the act of suppression. You mentioned the use of a shaped charge, and I just -- 1 thought it was meaningful to have you expand on that for people who are perhaps not familiar with -– this is -- is it not a high explosive?

WITNESS TYSON: Yes, it is. That system that we worked on, I did mention that there are no systems currently installed on Navy aircraft that use active explosion suppression.

That was a development test that we did, and we did do testing where we had an ullage that was explosive. It had a mixture of gasses in it that was flammable, and we commanded the det cord to go off to see if it would add to the problem, and we were not able to do that. Now, of course if we were to install a system like that on an airplane, I expect that it would get careful scrutiny to make sure.

There was another issue we were also concerned with when we did that investigation, and that is what happens if this is under -- under -- beneath the surface of the fuel and it goes off. Will that then create the hydraulic dram phenomena that Dr. Ball mentioned?

We had data -- we collected data to support that, and we didn't see that as a problem, either. But, those are the kinds of issues you have to deal with when you go to install a system such as this for protection of an aircraft.

MR. ANDERSON: Thank you. Could I also ask you about a non-high explosive, use of perhaps gas generating squibs? Has that been explored? -- a squib being a small detonator device that ignites a powder that burns slowly and creates a lot of gas.

WITNESS TYSON: Yes. As some of you might be aware, that technology is being explored heavily in the aircraft survivability community to partially take the place of Halon, because these gas generators produce copious amounts of inert gas, CO_2, nitrogen and water vapor.

Yes, we have tested those components in the application of ullage explosion suppression. It was a joint effort between Northrop Grumman Corporation and the Joint Technical Coordinating Group on Aircraft Survivability that Dr. Ball mentioned earlier, effort in testing that at China Lake.

It was a first look at a new technology, and we hope as the technology for the application of fire protection matures we can test it again. We weren't all that successful the first time.

MR. ANDERSON: Before we leave the Navy, I just want to make one more comment on the OBIGS nitrogen system. It was my privilege to hear somebody describe that from a chemical engineer's point of view, and I believe they related the molecular sieve. Is that the technology in use by the Navy on the OBIGS gas converter?

WITNESS TYSON: The one I described was permeable membrane, I believe.

MR. ANDERSON: Permeable membrane.

WITNESS TYSON: Molecular sieve is a different process.

MR. ANDERSON: Okay.

WITNESS TYSON: The permeable membrane has no moving parts once you get high pressure air to it. The molecular sieve requires that you pressurize and repressurize a bed of Z-like material so that the constituents of air that you don't want can be separated from the nitrogen and you can get nitrogen enriched.

MR. ANDERSON: So, essentially where I was going with that was that it was compared to a reverse osmosis system, which I think people are more familiar with where you desalinize sea water.

WITNESS TYSON: The permeable membrane is very similar to that.

MR. ANDERSON: Yes. Okay, and one last thing, Mr. Tyson. On the issue of fuels, because I think that is an important issue that we will continue to talk about even after we leave the military side of this problem.

Could you talk about -- your service is unique in that you have unique requirements on board ship, and you are probably the prime user of JP–5 fuel which has been mentioned several times here.

Do you have any comments on its use aboard ship?

WITNESS TYSON: I will do my best. That is not really my field. The primary reason that the Navy on ship board -- and I hope I don’t mis-speak -- uses JP-5 is to minimize the fire hazards associated with handling aircraft and refueling them on the deck.

JP-5 has fewer volatiles, it is a narrower cut of fuel when it is distilled and therefore the higher volatiles that evaporate early at lower temperatures are not present, and it makes it safer to handle on the deck.

Now, what does that do for us in the ullage from an aircraft survivability point of view? It simply shifts the flammability curve, the nationalized flammability curve that Dr. Ball showed us, to the right. It doesn’t do away with it, but it puts it at a different location in altitude and temperature.

MR. ANDERSON: Thank you very much. Mr. Lauzze, could you share with us some of the development concerns or considerations involved in protecting U.S. Air Force aircraft?

MR. LAUZZE: Thank you, Mr. Anderson. Yes. Like many other aircraft disciplines in aircraft survivability we feel it necessary to use a systems approach. We have to evaluate the whole aircraft, like the engine, the flight control system and structures, as well as the fuel system for vulnerabilities due to enemy hits.

Now, we also have to balance that vulnerability with the susceptibility of the system. As Dr. Ball earlier stated, the probability of getting hit in the first place, and obviously if you carried it to an extreme we could make an airplane with such low vulnerability that it couldn't perform its mission, it is too heavy and would actually get hit more often.

SO, obviously, our primary goal is to make sure we approach it in a balanced way.

MR. ANDERSON: Following on from there, what techniques does the Air Force use to suppress the fuel tank explosion similar to our parallel thoughts of Mr. Tyson?

MR. LAUZZE: The primary systems the Air Force uses is -- most of them I have mentioned before. The liquid nitrogen system in the C-5 I believe you talked to a few minutes ago; there is an on board inert gas generating system in the C-17, OBIGS; we use Halon in the F–16, and I believe that is the only DOD aircraft that uses Halon; and we use reticulated foam.

MR. ANDERSON: Could you carry on with your experience in using foam both in large and small aircraft?

MR. LAUZZE: Within the Air Force we use foam in aircraft as small as the A–10 and as large as the C–

130. It is also used, I believe, in a similar arrangement in the Navy's P–3, as similar to the C–130.

I did bring one slide with a little bit of a success story, if you take a look at the monitor there (indicating) . This is a picture of an A-10 from Desert Storm.

As you can see, the right hand wing was hit by enemy fire, by what was probably a very large threat. Due in a large part to the foam and just the ruggedness of that airplane, we were able to bring that airplane home and the pilot landed the aircraft safely.

The point is –– the bottom line is, foam works .

MR. ANDERSON: Thank you. Could you talk a little bit about the static interaction with the foam and, you know, we talked earlier about the mechanism of suppression used by the foam.

MR. LAUZZE: Some of the earlier foams had a static problem primarily in the refueling –– in refueling exercises where the foam actually –– or, the fuel actually ran through the foam. A static charge would build up on the foam.

I believe that is one reason the Air Force in many cases has added an anti–static agent to our JP–8, but it has also resulted in the development of the newer foams, and the type that Hardy showed actually has an ingredient in it that actually helps bleed off the static in the fuel so we don't have the static problem.

MR. ANDERSON: Thank you. Feel free to solicit help from Mr. Tyson or Dr. Ball on this question, but I think it is important to talk a little bit about the future of Halon.

I know the Air Force is looking at alternatives, and one of those alternatives I believe he has all ready talked a little bit of is active systems. But, could you give us anymore feel for what affects that may have on your existing systems?

MR. LAUZZE: Well, there is two thrusts going on in the Halon replacement area, basically short term. We are actively -- with the Navy and the Army actively looking for a chemical which we could use as a replacement for the Halon chemical.

HFC–125 is the current chemical of choice, although there are others still being looked at. There are some other active type systems, as Hardy mentioned earlier, and there is a long range program sponsored by DOD, the Next Generation Fire Protection Program, which is being highly supported by DOD.

SO, there is both a short term fix and a long term fix in the works and, Hardy, would you like to add to that?

WITNESS TYSON: Yes, Ralph is correct. The DOD is intensely interested in solving this problem for our use. I would like to point out there are two applications that we are looking at to replace Halon for. One is fire-fighting, whether it be a system on an airplane or whether it be on the ground. The other is explosion protection.

I have tested –– we have tested at China Lake the first -- some first generation chemical replacement agents for Halon in the application of inerting for fuel tank ullage. Then I mentioned earlier the gas generator work that we did for the same application.

It is probably the case that we are not going to find any one replacement for Halon. It will depend on the application what technology we turn to.

MR. ANDERSON: If I understand the problem correctly, the problem with replacing Halon is finding something that is equally effective and is light–weight and easily handled. Is that an accurate summary, or have I missed something?

WITNESS TYSON: I am not sure I could capture all of them, but that is a good summary of the most important ones.

MR. ANDERSON: Isn't it also true that this is the primary fire extinguishing agent used on aircraft engines?

WITNESS TYSON: Yes, that is correct. It is being used in aircraft engine bays or in the cells since, I believe, the 70's almost exclusively, and that is an issue we are working really hard.

MR. ANDERSON: So, that should put some urgency into the search for replacement, shouldn't it?

WITNESS TYSON: Yes, it should.

MR. ANDERSON: Because without the protection of engines, there is going to be a relaxation, or some degradation unless an equally effective replacement is found.

WITNESS TYSON: Yes.

MR. ANDERSON: Mr. Chairman, at this point I would suggest that we break the panel. We are ready to transition to the application of this technology in the commercial aviation world.

CHAIRMAN HALL: Well, at this point, Mr. Anderson, the Chairman is numb, so I am going to suggest that we save that, because it is so important, and begin at that point in the morning at nine o'clock.

Let me say that one item of clarification here -- we discussed the Madrid 747 that was a fuel air explosion because of lightning. That was line 73, which I assume is the 73rd 747 off the assembly line, and TWA 800 was line 153, which was the 153rd plane.

MR. RODRIGUES: That is correct, Mr. Chairman, and line 73 was delivered in September, 1970.

CHAIRMAN HALL: Fine. Does anyone have anything else they want to clarify before we end today's session?

(No response.)

If not, I will look forward to hearing from this panel again in the morning, and concluding the last day of our hearing tomorrow. We will stand in recess until 9:00 a.m. tomorrow morning.

(Whereupon, at 5:30 p.m. the hearing was adjourned, to reconvene at 9:00 a.m. the following day in the same location.)

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